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SECTION OF GEOLOGICAL SCIENCES

OROGENY, GRAVITY TECTONICS, AND TURBIDITES IN THE MONGHIDORO AREA, NORTHERN APENNINE MOUNTAINS, ITALY*

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Introduction

On the site of the Northern Apennine Mountains of Italy during mid-Cenozoic, extensive deposition from turbidity currents, compressional orogenic movements, and gravity sliding on a regional scale took place in a deep sea environment. Structural and surficial relief measured in thousands of meters developed beneath the sea during folding, but final uplift to mountainous heights came only in late Cenozoic, as late as early Pleistocene in the northern ranges.†

Monghidoro Area

Near Monghidoro, along the crest of the Apennine Range between Bologna and Florence, features of gravity tectonics are strikingly displayed. FIGURES 1 and 2 illustrate the nature of the geologic problems. To the south and east, great, complex, plunging anticlinal masses of Oligocene and Miocene sandstone form the basement. Between the uplifts and covering their plunging ends is a sheet of heterogeneous but generally much older materials, the "argille scagliose" (scaly clays) of Apennine geologists.

The stratigraphic section in the Monghidoro area is shown graphically in FIGURE 1. Macigno and marnoso-arenacea (literally "marly sandstone") at the base of the section are components of the Apennine "flysch." Each formation consists largely of thick to thin beds of laterally continuous, poorly sorted sandstone, grading upward into fine-grained micaceous sandstone, silty shale, or clay shale. These graded sandy beds are the "resedimented" sands of Migliorini (Kuenen and Migliorini, 1950), or "turbidites" of Kuenen (1957), and are generally believed to have been deposited from density or "turbidity"

*This paper, illustrated with slides, was presented at a meeting of the Section on January 5, 1959. The field work on which this article is based was made possible by a grant under the Fulbright Act for study in Italy.

†For a definitive treatment of the geology of the Northern Apennines and a comprehensive bibliography, see Merla, 1951 (review in English, Maxwell, 1953). A group of important recent papers was published in volume 75, No. 3. Boll. Soc. Geologica Italiana, 1956. See also Azzaroli, 1955; Merla, 1957.

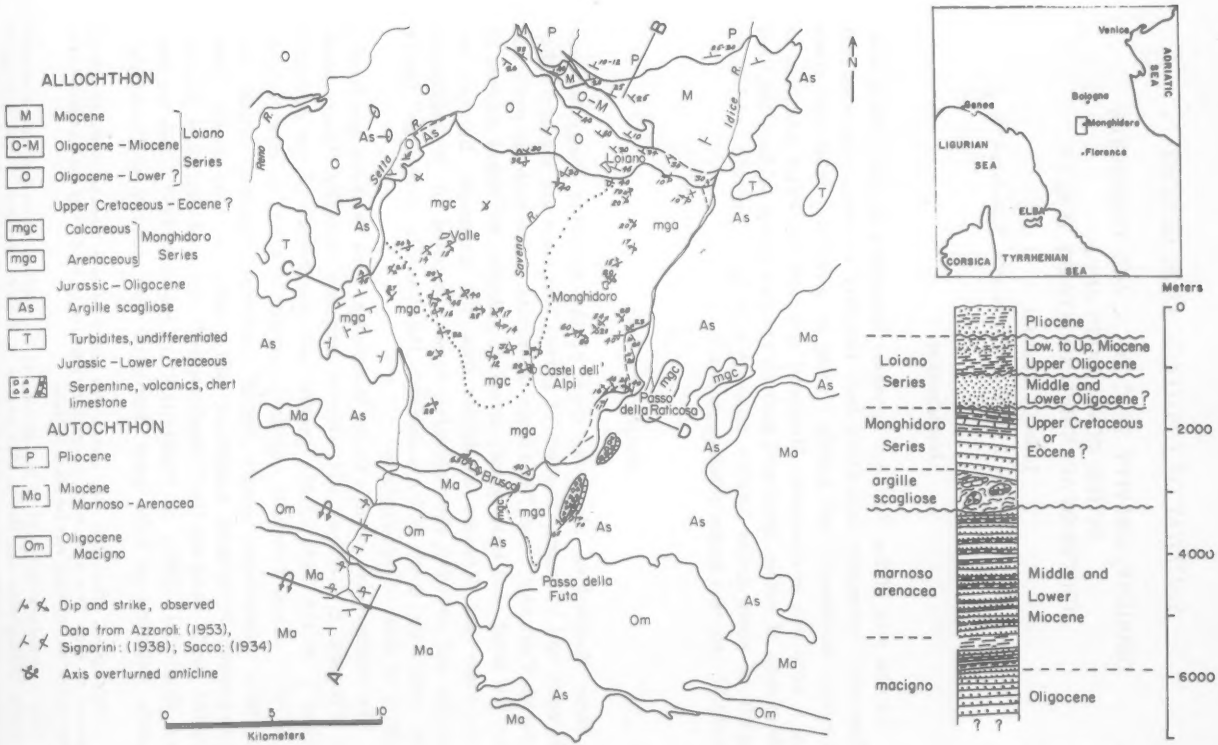

FIGURE 1. Monghidoro area, crest of Apennine Mountains between Bologna and Florence, Italy. Map modified from Sacco (1934) and from Azzaroli (1953), Signorini (1942), and Merla (1957).

from Azzaroli (1953), Signorini (1942), and Merla (1957).

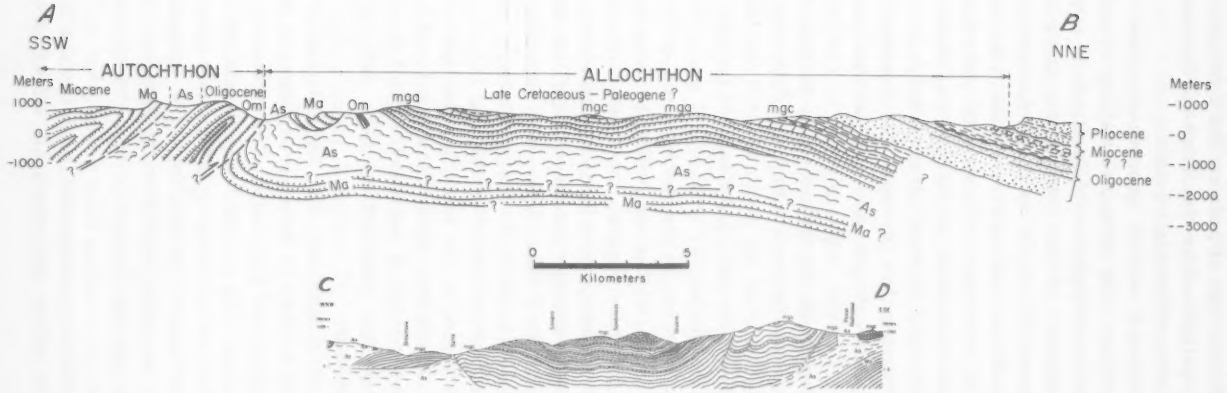

FIGURE 2. Cross sections *A* and *B* and *C* and *D*. Location of sections and key given in FIGURE 1.

currents. The shaly or marly tops of beds are the finer materials of the density current, plus pelagic clays deposited in intervals between successive arrivals of sediment-bearing currents.

Distinctive bottom markings, such as groove casts, flute casts, load casts, worm trails and casts, and the graded bedding in such "resedimented" formations are exceedingly useful in structural mapping; they permit accurate determination of the original deposition sense, and hence of tops and bottoms of beds, at nearly every outcrop (Signorini, 1936). In addition, certain features such as groove casts, current bedding, and alignment of carbonaceous fragments and other particles indicate the direction of movement of the parent density current. A study of these directions in the macigno and marnoso-arenacea (ten Haaf, 1957) shows that the currents that deposited them traveled from northwest to southeast, parallel to the present structural trends in the Apennine Mountains.

Macigno sandstone ridges make up the core of the Northern Apennines, while ridges of the marnoso-arenacea form the northeastern ranges to the east of the Monghidoro area and south of Forli and Rimini. It is probable that the macigno thins out rapidly north of the anticlinal ridge shown in the lower part of FIGURE 1.

Lying in apparent conformity on the macigno and on the marnoso-arenacea, and involved in the folding and faulting of these rocks, is the argille scagliose. As the name implies, the complex is characterized by chaotic clay but, in addition, about fourteen distinct rock types and recognizable sedimentary sequences ranging in age from late Jurassic to Miocene occur as exotic blocks, slabs, and mountainous masses within and on the clay (Merla, 1956). Many of these exotic materials are not known to outcrop in place in this part of Italy.

One of the most interesting of the exotic masses within the argille scagliose is the great Monghidoro sheet (FIGURES 1 and 2). Signorini (1938) recognized that the rocks of the sheet differed from the nearby marnoso-arenacea, which they somewhat resemble, and that they were for the most part upside down.

The Monghidoro sheet is synclinal. The top (original bottom) is an interbedded sequence of medium- to dark-gray argillaceous and fucoidal limestone, calcareous shale, and fine, well-graded calcareous sandstone. Downward in the sheet (originally upward in the section) the interbedded sandstone layers become more numerous and coarser grained and the limestone beds correspondingly less abundant. The calcareous part of the Monghidoro series somewhat resembles the albarese Eocene limestones and shales that are abundant and widespread as exotic masses in the argille scagliose.

The bottom of the sheet as now exposed (originally the top) consists of graded sandstone in uniform and remarkably extensive beds one to

eight feet thick.* At the base the thicker beds are coarse-grained, poorly sorted sandstone or fine conglomerate, many with rounded pebbles of quartz and a few of fine-grained biotite granite to one half inch in diameter. Feldspar is abundant. Coarse cleavage fragments of pink and salmon-colored microcline abound, and they help to differentiate this coarser phase of the Monghidoro series from the otherwise similar and equally feldspathic macigno and marnoso-arenacea.

The basal coarse sands and fine conglomerates grade upward into fine, laminated micaceous sand, rich in carbonized plant fragments. Fragments of gray shale are also common in the finer sand above the base. On top of the fine sand may be three to eight inches of dark gray shale. The sand and part of the shale, expecially the silty shale, is uniformly calcareous and generally medium gray in color. A few inches of noncalcareous, dark gray shale that may be present at the top of the bed are probably of pelagic origin. Intricately convoluted structures characteristic of the sandy layers indicate slumping during or following sedimentation. Such structures terminate upward against the pelagic shale layers.

At the northeast edge of Monghidoro and approximately one-half mile farther north along the road to Loiano, sparse faunas of arenaceous forams were found in the dark gray, noncalcareous pelagic shale above graded sandstone beds. The foraminifera from the outcrop nearest town were identified as probably Paleogene, while those one-half mile away and approximately on strike were considered to be late Cretaceous by another worker. The difference of opinion probably reflects the non-diagnostic character of the arenaceous Foraminifera (*Trochamminoides, Ammodiscus,* were identified). The series is certainly pre-Oligocene, as indicated below and, if the calcareous portion is equivalent to the alberese, it is probably Eocene.

Numerous determinations of sense of sedimentation by graded bedding and bottom markings show that nearly the entire sheet is inverted (FIGURE 1). Small areas on the west, east, southeast, and northeast edges are right side up, however. The contacts between upright and overturned portions of the sheet are zones of structural disturbance, probably faults, and the present upright portions seem to represent crumpled and "overturned" margins of a sliding upside-down sheet.

Although the sheet as a whole is only gently flexed, it is broken locally by numerous small faults and folds. Much of this minor deformation probably occurred while the sediments were still unconsolidated, as indicated by sharp folding of thick limestone and sandstone beds without fracture or cleavage, and by flowage of beds associated with minor faulting. Even today the shalier portions are capable of flowage; an extensive land slide area in the valley of the Savena near Castel del

*Sedimentary features are described as though the rocks were in their original attitude of deposition.

Alpi closely resembles the argille scagliose in which the sheet is embedded. Bruern (1941) mapped a diapiric intrusion of argille scagliose in this area, although the field evidence for a landslide origin seems clear.

Above the argille scagliose complex in the Monghidoro area are a series of littoral and neritic sands, shales, and marls, the Loiano series of FIGURE 1 (Merla, 1951; Lipparini, 1944), which are approximately equivalent in age to the macigno and marnoso-arenacea several thousand feet lower stratigraphically. At the base is the "Loiano molasse," a thick-bedded to massive, coarse, well-sorted sandstone and conglomerate, deposited on the argille scagliose and across the bottom side of the overturned Monghidoro sheet. Pebbles of sandstone and limestone derived from the Monghidoro group are abundant, as are pebbles of basic volcanic, granitic, and other crystalline rocks apparently derived from the argille scagliose. Well-preserved reworked Foraminifera—*Nummulites* and *Lepidocyclina*—persumably came from the same source.

Above and at considerable angular discordance to the Loiano molasse (Azzaroli, 1953) are fossiliferous clays, marls, and sandstones of the upper part of the Loiano series, ranging in age from early(?) Oligocene through late Miocene (Tortonian). A transgressive-regressive Pliocene sequence overlies the Loiano series and is stratigraphically continuous with the Pliocene sediments of the Po basin.

Interpretation

Major problems. The stratigraphy and structure of the Monghidoro area pose several difficult problems, of which the most intriguing are: (1) the mode of the emplacement of the argille scagliose complex; (2) the mechanism of formation of the great overturned Monghidoro sheet; and (3) the relation of the Oligocene-Miocene shallow-water macigno and marnoso-arenacea of equivalent age.

(1) The mechanism of emplacement of the great discontinuous sheet of the argille scagliose complex is the subject of much controversy. It has been explained as a marine sediment deposited essentially where it now occurs, as a far-traveled nappe of Alpine type, as a product of local diapirism and limited surficial sliding, and as a far-traveled allochthonous complex, originating either to the northeast, or to the west of the present Tyrrhenian coast. For a bibliography and a discussion of these theories the reader may consult Merla's comprehensive works (1951, 1957) and, for a brief statement of objections to a far-traveled origin, DeSitter, 1956.

The first two theories of origin, that is, as a marine sediment and as a nappe are no longer tenable because of the demonstrated hetero-

geneity and chaotic structure of the complex. The problem of a local versus far-traveled origin is not definitely settled, but most Italian geologists with long field experience in the Northern Apennines favor a place of origin west of the present Tyrrhenian Coast; many of the exotic inclusions appear to have originated in this area, the argille scagliose becomes less chaotic toward the west (Trevisan 1956, 1950), younger components appear in the argille scagliose to the northeast, and the size and number of ophiolite masses decrease markedly from west to east. Evidence has also been presented that the argille scagliose was emplaced prior to late Miocene (pre-Tortonian) in the Tyrrhenian coast area (Trevisan, 1951), but did not reach the east margin of the Apennines until the end of the Miocene – post-Tortonian pre-Messinian (Ruggieri, 1956).

In addition to evidence pointing positively to a Tyrrhenian origin, there are arguments against a theory of local diapiric origin for the argille scagliose. It is highly unlikely that large continuous sheets of exotic rocks measuring tens to hundreds of square kilometers, such as the Monghidoro series, the overturned sheet of macigno capping Monte Cimone (Danielli, 1953), and others mentioned by Merla (1956) could be brought up diapirically for thousands of feet through narrow channels and spewed out whole on the surface. It is also significant that the nearest exposed authochtonous rocks of equivalent age to the great exotic masses are invariably of different facies (Merla, 1956).

(2) The mechanics of origin of the overturned Monghidoro sheet can only be conjectured. Overturned "flap" structures up to 3.5 k broad have been observed in southwest Persia (Iran) by Harrison and Falcon (1934). Flaps formed in this manner cannot exceed in length the distance from the crest of the parent fold to the adjacent valley floor, measured along the bed forming the flap. The method would require modification, therefore, to account for the Monghidoro sheet, a minimum of 15 k broad.

FIGURE 3 illustrates a possible mechanism. The Monghidoro series, still unconsolidated, was buried by argille scagliose, then arched up into a broad anticlinal uplift and probably faulted, although faulting is not indicated on the cross section. The Monghidoro sediments would be only slightly more coherent than the overlying argille scagliose. If, then, a slab of Monghidoro sediment became detached near the crest of the structure through faulting or slumping, the argille scagliose and included Monghidoro sheet might flow by gravity down the northeast-facing slope. The subsequent rise of a second ridge in the position indicated would give new impetus to the slide and complete the formation of the 15-k broad overturned "flap."

(3) Perhaps the most difficult problem of the Monghidoro area is the origin of the Loiano series and its relation to the marnoso arenacea and macigno of equivalent age (FIGURE 1). To the east, in the Santerno

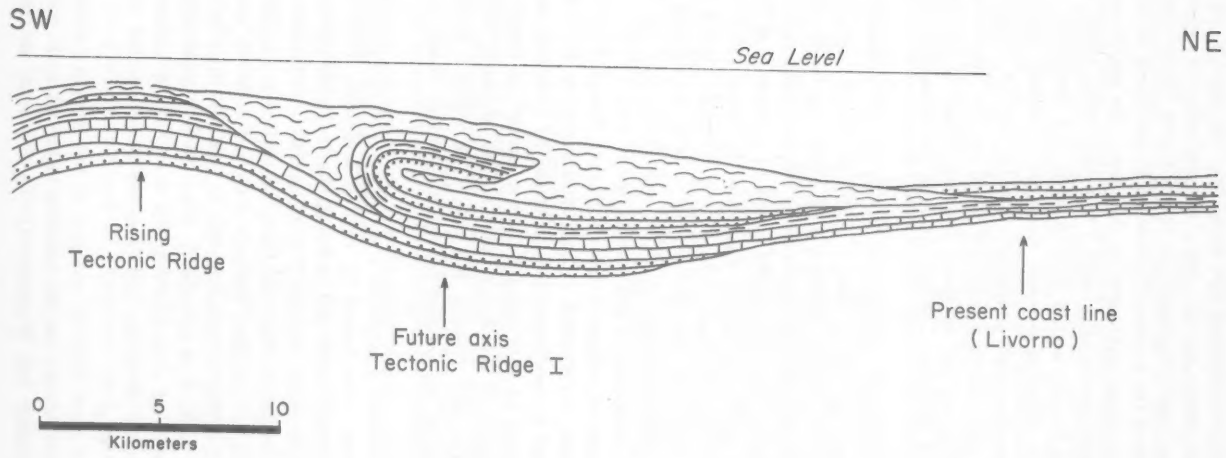

FIGURE 3. Possible origin of overturned sheet of sediments, Monghidoro series. Macigno is being deposited on the toe of the argille scagliose slide to the northeast.

Valley, sedimentation was continuous from the marnoso arenacea through the Messinian gypsiferous shale (Merla, 1951). In the Monghidoro area, however, the marnoso arenacea is overlain by several thousand meters of allochthonous argille scagliose, including the overturned Monghidoro series, plus the Loiano series of littoral and neritic sediments that were deposited on the argille scagliose and its exotic inclusions.

Wiedenmayer (1950) considered the Loiano series to be autochthonous, formed after the deposition of the argille scagliose in the area. The difficulties imposed by this assumption are obvious, as the argille scagliose and Loiano series overlie the younger and well-dated lower and middle Miocene marnoso arenacea.

Conditions of deposition of "turbidites" (Kuenen, 1958) and the fossil assemblage (Emiliani, 1952) indicate that pelagic conditions existed in the area of the northern Apennines during Oligocene and Miocene (macigno, marnoso arenacea). Signorini (1942), Merla (1951), and Azzeroli (1953) therefore argue that sediments of the littoral and neritic Loiano series must have been deposited on the argille scagliose far from its present outcrops. Because many of the exotic inclusions of the argille scagliose seem to have been derived from the Tyrrhenian area, they postulate a Tyrrhenian or at least southwestern Tuscan provenance for the Loiano series also, with subsequent transport northeastward on the sliding argille scagliose. In this interpretation the lower Oligocene (?) Loiano molasse must have been deposited on the argille scagliose near a shore line west of the depositional area of the macigno, hence west of the present Tyrrhenian coast. The upper Oligocene-Miocene deeper water sediments of the series, on the other hand, could have been deposited on the moving allochthonous sheet somewhat to the northeast, nearer the present outcrop but south of the trough in which marnoso arenacea was accumulating.

The Pliocene sediments, transgressive over both the Loiano series and the argille scagliose date the arrival of the sliding mass at the border of the Po basin. The Pliocene itself has been moved several kilometers, however, coincident with mid-Pliocene folding (Ruggieri, 1956).

Relation of Argille Scagliose to Deformation of Autochthon

Merla (1951, 1957) gives evidence that deep water conditions and continuous sedimentation persisted from Jurassic through early Miocene in the central and maritime portions of the northern Apennines, and through late Miocene in the northeastern Apennines. In this submarine environment the macigno and marnoso arenacea seem to have been deposited in northwest-trending troughs, parallel to the general strike of the present Apennines (Kuenen 1958, ten Haaf, 1957). In the same submarine environment the argille scagliose moved from the Tyrrhenian

coast almost to the Adriatic, receiving sediments on its surface, overriding first the macigno, then the marnoso arenacea, and incorporating parts of these and of overlying sediments in the sliding chaotic mass.

In order for sliding to occur, a slope must, of course, be provided. The critical angle of slope of the glide surface is not known for the specific conditions outlined. Rigby (1957) estimates a critical glide angle of about 2° for various areas of gravity sliding in bedded sediments in the United States. If we assume this angle for the argille scagliose and a minimum of 150 k of northeastward movement, a single uplift in the Tyrrhenian area 10,600 m. high would be required to provide the critical slope. The two-degree angle is probably too small to cause movement of the extent and continuity visualized for the argille scagliose, and the required uplift to cause movement would be correspondingly higher. Furthermore, much steeper slopes and large-scale faulting would seem to be required for formation of large overturned sheets of sediments and of slabs and wedges of such rocks as mylonitic granite, serpentine, and gabbro.

Migliorini (1948) and Merla (1951) visualized a series of successively rising "tectonic ridges," the oldest in the Tyrrhenian Sea, and each succeeding ridge forming to the northeast of its predecessor. The great ridges are asymmetrical, with their longer and gentler slopes facing northeast. As the ridges rose successively in a deep sea environment the superincumbent unconsolidated material slid down both flanks, but the longer slopes to the northeast ensured transport of most of the material in this direction. A series of ridges thus provided the slope for long-distance transport by gravity sliding, and argille scagliose, plus debris accumulated from overlying sediments and underlying autochthonous rocks, moved by stages from the Tyrrhenian nearly to the Adriatic Sea.

Summary

Within the Northern Apennines and in the comparatively short time interval of the Oligocene and Miocene, basins developed successively from southwest to northeast and were filled largely by sediments transported from the northwest as turbidity currents. A series of parallel orogenic ridges developed successively from southwest to northeast, with tectonic transport and overthrusting generally to the northeast, and a great allochthonous sheet of heterogenous clay and erratic blocks was transported in the same direction by gravity sliding, coincident with the rising of each ridge. The sheet presumably originated west of the Tyrrhenian coast during the late Oligocene, covered much of maritime Tuscany in early Miocene, and reached the present northeast margin of the Apennines at the end of the Miocene. In its travel the allochthonous

material incorporated rocks from the sea floor which it overrode, as well as normal marine sediments deposited on its surface. Some of the latter may have moved many kilometers on the sliding mass without complete loss of continuity.

Acknowledgments

It is a pleasure to acknowledge my indebtedness to G. Merla, head of the Institute of Geology, University of Florence, Florence, Italy, to his able staff, and to the late C. I. Migliorini for their hospitality and for the stimulation afforded by this active center of geologic research. I also thank J. C. Young for criticizing the manuscript.

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SOLUTIONS OF ALKALI METALS IN AMINES AND ETHERS*

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It has been known for many years that alkali metals dissolve reversibly in liquid ammonia to give blue, electrically conducting solutions. These somewhat exotic solutions have attracted a number of talented chemists to their study. Solutions of alkali metals also occur in several amines and have recently been discovered to occur in several ethers, as well. Despite nearly one-half century of investigation, the essential nature of this sort of solution is still not completely clear.

Quantitative studies have been concentrated on the Na/NH_3 and K/NH_3 solutions. A variety of observations on other systems has been recorded, but they tend to be scattered. Partly for this reason, theories of alkali metal solutions have been judged largely by their success in interpreting the behavior of the ammonia solutions.

Solutions of alkali metals in the various solvents (liquid ammonia, methylamine, ethylene diamine, dimethylamine, tetrahydrofuran, and 1,2 dimethoxyethane, to name a few) display[1] a fine blue color, conduct electricity, reduce a large number of chemical compounds, and deposit the metal unchanged upon evaporation of the solvent. When the solubility permits the attainment of concentrations of several moles per liter, the characteristic blue color frequently goes over into a bronze color with a distinctive metallic luster. Electric conductivity in this concentration range becomes very high, approaching values ordinarily encountered only for metals. Separation into 2 liquid phases has been found in several cases.

Individual differences are noted in solubilities, electric conductivities, magnetic properties, and absorption spectra, although regularities appear in these properties as well. The over-all similarities are so pronounced, however, that it seems reasonable to expect that a general theory could be found that would deal with all such solutions. The theory might be expected to contain several parameters, such as equilibrium constants, which would vary from system to system.

In this communication we test the principal current theories of the structure of solutions of alkali metals by comparison with the properties of a number of systems, particularly those of some recently studied ethers.

In a series of cleverly designed experiments on the sodium/ammonia system Kraus[2] laid the foundations of our knowledge of metal solutions. He showed that the negative charge carrier is the electron, accounting for

*This paper, illustrated with slides, was presented at a meeting of the Section on January 6, 1959.

about seven eighths of the transport of electric current in dilute solutions and all of the transport in concentrated solutions. His data for the electric conductivity of dilute solutions indicated that ion pairing took place, and he estimated that the formation constant of the ion pair in sodium/ammonia at the boiling point of liquid ammonia has the value 0.03. Other more recent studies[3] on the lithium/methylamine system in the range of moderate concentration led to similar conclusions. Kraus also explored some of the reactions of such systems, including such bizarre reactions as the formation of a green, negatively charged species of lead. In recent years these systems have come into widespread use in organic syntheses.[4]

An important advance was made when Freed[5a] and Huster[5b] measured the static magnetic susceptibilities of solutions of sodium and of potassium in liquid ammonia. Each unpaired electron is expected to contribute one Bohr magneton to the paramagnetism of the solution, whereas paired electrons contribute nothing. In addition, both paired and unpaired electrons contribute a very small diamagnetism whose magnitude depends somewhat on the environment of the electron. It was found that the susceptibility corresponds closely to one unpaired electron per atom of metal in very dilute solutions, but that the apparent molar paramagnetic susceptibility falls off with increasing concentration, indicating that the electrons are being paired in some fashion. This phenomenon is interesting, not only because of the information that it gives about the sodium/ammonia system, but also because it provides an example of a transition between the dilute Boltzman gas of electrons and the concentrated, hence degenerate, Fermi gas. By examining the effect of temperature on this pairing process it was possible to show that the electron pair is energetically favored over two unpaired electrons. Of course, the entropy favors the two unpaired electrons in dilute solutions.

Later measurements of electron paramagnetic resonance (epr) on the sodium ammonia and potassium ammonia systems confirmed these results.[6] In addition, these data permitted separation of the paramagnetic and diamagnetic contributions of the electrons, revealing that the electrons were spread over a moderately large volume element. Also, the epr studies showed that the sodium/ammonia system displays the narrowest known resonance. The interpretation of this fact involved postulating an interaction between the electron and the protons on adjacent ammonia molecules, so-called "motional narrowing," a topic to which we shall return. Measurements of the partial molal volume[7] of the metal in ammonia revealed that there is a pronounced expansion upon solution of sodium.

Extensive data on optical absorption spectra have become available only recently.[8] In general, the spectra show one of two absorption maxima: either near 6500 to 7000 Å or near 13,000 to 15,000 Å. There appears to be a correlation between the appearance of the 15,000 Å peak and the appearance of paramagnetism.[9] Each peak is accompanied by an absorbing region extending from the maximum through the visible into the

ultraviolet region. Irradiation of frozen solutions in this tail lead to bleaching of the color[10] and, in the liquid, lead to a photoelectric effect.[11] Irradiation in the maximum did not produce either of these effects, leading to the conclusion that the absorption maximum involves a transition to a bound state and that the continuous tail involves a transition to an unbound state of the electron.

On the basis of these and similar data one of the two leading theories of these solutions was formulated. It was proposed by Kraus,[2] extended and modified by Ogg,[12] Lipscomb[7] and others, and has been stated most recently by Kaplan and Kittel.[13] This model is as follows:

(1) The metal atoms are ionized in solution.

(2) The electrons removed from the metal atoms are located in cavities in the liquid, the cavities having approximately the volume of 2 to 4 ammonia molecules.

(3) The electrons in the cavities are in equilibrium with respect to the following reaction, where e_2 represents 2 electrons in a singlet state (antiparallel spins) in one cavity:

$$2\ e = e_2 + 0.2\ ev$$

that is, the dissociation energy of a cavity containing two electrons each (e_2 center) with respect to 2 cavities containing 1 electron each (e centers) is 0.2 *ev*.

(4) The electrons associated with the cavities may be thought of as in molecular orbital states on the protons of ammonia molecules adjacent to the cavities.

(5) There is a conduction band about 1 *ev* above the cavity states.

This model succeeds admirably in rationalizing the data cited thus far. It has been applied in detail only to the ammonia system but, in principle, it could be applied equally well to all the other solvents. The sole peculiarity that this theory would attribute to the ammonia system is that the ease of rotation and diffusion of the ammonia molecule cause the dipolar and hyperfine interaction of the nuclei of the atoms lining the cavity with the electron within that cavity to be of such a magnitude that the epr line is markedly reduced in width. This "motional narrowing" would be expected to be much more important for ammonia than for larger molecules.

Becker *et al.*[14] criticized this model, pointing out several inconsistencies. They noted that the basic assumption of the cavity model, namely, that the electrons are completely independent of the metal atoms, does not accord with the differences found in the magnetic susceptibility and in the electric conductivity for the different alkali metals. Furthermore, the arguments based on absorption spectra measurements were considered to be misleading since very few spectral data were available until very recently. Other shortcomings of the cavity model pointed out by these authors are the difficulty in explaining the nature of the energy of pairing

the electrons, the source of the energy sufficient to form large cavities, and the unusually large limiting conductance for an electron in such a cavity. The model proposed by these authors is as follows:

(1) The solute is pictured as 4 species in equilibrium. A neutral species, called a monomer, consists of an alkali metal ion surrounded by approximately 6 oriented ammonia molecules with an electron circulating around the protons of the ammonia molecule. The 2 charged species are a solvated metal ion and an electron arising from the dissociation of the monomer. Finally, there is a dimer, composed of 2 monomers bound principally by exchange forces.

(2) Equilibrium among these species is described by the equations

$$M = M^+ + e^- \quad K_1 = \frac{[M^+][e^-]}{[M]}$$

$$M + M = M_2 \quad K_2 = \frac{[M_2]}{[M]^2}$$

This model successfully treats the concentration dependence of the electric conductivity and magnetic susceptibility for sodium and potassium, as well as their temperature dependence. It also permits approximate calculations of the energy differences between the various species in order to estimate roughly the constants K_1 and K_2. The peak in the absorption spectrum is attributed to the fact that the electron is excited in the potential well around the alkali metal ion. We argue that this proposal is supported by the evidence that the absorption spectrum is nearly independent of the nature of the metal, but depends on the solvent. The role of the positive ion is restricted to providing a center for the periodic motion of the electron. The dimer can also show such transitions, and they will occur at roughly the same energies.

Powerful support was given to this theory by the nuclear magnetic resonance studies of McConnell and Holm.[15] These investigators measured Knight shifts in the nuclear magnetic resonance of N^{14} and Na^{23} nuclei in moderately concentrated solutions of sodium in liquid ammonia. The results of this investigation can be presented in the form of a quantity measuring the density of nuclei of each type near unpaired electrons. It was concluded that the values of this quantity clearly demonstrated an appreciable density of Na^{23} nuclei at unpaired electrons. The observed Knight shifts can be interpreted as arising from the monomer species in which the electron is thought of as moving in a highly expanded *s*-like orbital around the Na^{23} nucleus. The substantial shifts for N^{14} were found to be essentially independent of concentration, indicating that the interaction of the electrons and N^{14} nuclei is independent of whether the electron is associated with the positive ion. The significance of this observation is not completely clear. Finally, no shift at all was detected

for the H^1 nuclei. This is a puzzling result, since it indicates that there is a considerable electron density near the N^{14} nuclei but none near the adjacent protons. This is difficult to reconcile with the model that locates the electrons on the proton shell formed by directed ammonia molecules around the positive ion. Pitzer[16] has noted that the occurrence of a node at the hydrogen atom in the wave function of the unpaired electron centered on the nitrogen nucleus would account for the failure to find an appreciable density of unpaired electrons near protons. On the other hand, if there is little electron density near the protons, the source of the polarization energy that stabilizes the monomer is difficult to see.

The spectroscopic and magnetic studies of Fowles *et al.*[9] on amine solvents containing various alkali metals lend support to the cavity model just as well as to the monomer-dimer model. These workers found it possible to correlate the absorption band near 7000 Å with the e_2 species and that near 15,000 Å with the e_1 species. That is, solutions that show only the first absorption maximum are not detectably paramagnetic, and the solutions that show the second absorption maximum are always paramagnetic. These investigators interpreted the irradiation experiments[10,11] as showing that the ejection of an electron (paired or unpaired) from its cavity is brought about by irradiation in the continuum of the spectra, but that irradiation in the maximum leads to excitation within the same cavity. They suggest further that ion-pair formation is important in amine solvents and leads to a considerable influence of the metal ion on the solvated electron. The crux of the matter would appear to be the extent to which the nature of the cation affects the state of the electron.

Very recently Cafasso and I[17,18] have carried out some measurements of absorption spectra, electric conductivities, and epr spectra of several alkali metal/polyether solutions.[18] We found that potassium, ribidium, and cesium dissolve in a number of polyethylene glycol dimethyl ethers, but that lithium and sodium are insoluble. Sodium, however, can be carried into a solution that already contains potassium. The absorption spectra of potassium, cesium, and solutions of sodium and potassium together are nearly identical, showing absorption maxima near 7000 Å and a tail extending through the ultraviolet. The rubidium solutions, however, display a maximum near 9000 Å, along with the usual tail. When potassium and rubidium are present simultaneously the two peaks appear together. Their relative magnitudes are unaffected by temperature or dilution. Although no epr was found in any solutions in ethylene glycol dimethyl ether itself, solutions in tetraethylene glycol dimethyl ether gave an interesting result. Potassium and cesium solutions are diamagnetic, but rubidium solutions show a small, definite paramagnetic resonance. In this solvent the rubidium spectrum has a maximum at 8900 Å, whereas the spectra for potassium and cesium show their maxima at 6900 Å. Furthermore, the cesium spectra has a small but distinct peak at about 10,000 Å. None of these solutions shows any further absorption as far into the infrared as 2.5 μ.

Cafasso and I also gave some preliminary measurements of electric conductivity. The most significant result is that the equivalent conductance of potassium in ethylene glycol dimethyl ether, after making due allowance for viscosity and temperature differences, is similar to that of lithium in methylamine. The former solution is diamagnetic and the latter paramagnetic (this is the first report of electric measurements on diamagnetic solutions of alkali metals in any solvent).

The occurrence of a substantial electric conductance in solutions that do not show free spins conflicts with the theory of Becker *et al.*[14] in its original form. In that theory the paramagnetic species are the solvated electron (condition unspecified) and the neutral monomer, while the diamagnetic species is the dimer. On the one hand, the absence of a paramagnetic resonance means that solvated electrons and monomers do not occur in these solutions in appreciable quantities. On the other hand, the dimer is incapable of carrying electric current. One is forced to postulate the existence of electron pairs that may be located in cavities or in the form of ion pairs with positive ions. (The other explanation for the absence of paramagnetism, that there is a quite unexpected spin-lattice relaxation time in these solutions, is considered to be unlikely here.)

By combining the solubility studies of Cafasso and myself[18] with the preliminary report of Down *et al.*,[19] it is possible to get an idea of the geometrical requirements for a satisfactory solvent. Dimethyl ether and diethyl ether, which are chemically very similar to the polyethers, do not dissolve the metals. When molecular models are made of the ethers that have been found to dissolve the metals, it may be seen that they are characterized by possessing configurations in which a cavity is lined with the negative (oxygen) end of dipoles. In almost all of these cases, as well as in the known amine systems, the formation of such a cavity automatically implies the existence of an adjacent cavity linked to the first one, which is lined with the positive (hydrogen) ends of the dipoles. The situation is pictured in FIGURES 1 and 2. In tetrahydrofuran and certain substituted polyethers, the cavities lined with hydrogen are partially blocked, but solution still occurs. No epr or conductivity data are available yet for these systems. Thus, the possibility of formation of a well-defined negative cavity for the positive ion seems to be the structural peculiarity common to all of the solvents for alkali metals.

Study of these ethers contributes yet another sidelight on the problem of the way in which the electron is bound here. It has not been possible to find a salt, such as potassium chloride, that will dissolve in the polyethylene glycol dimethyl ethers to give a conducting solution. If the electron is pictured as occupying positive cavities, the anion might be expected to do likewise, unless the cavity is too small. Another possibility is that the double negative charge attributed to the hypothetical electron pair might be required to establish sufficient polarization of the solvent. In that case potassium oxide might be expected to dissolve to

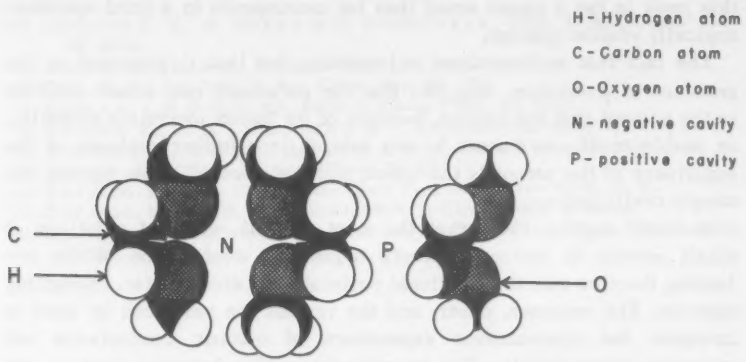

FIGURE 1. Cavity model of 1,2-dimethoxyethane.

give a conducting solution. This is not the case. Yet another possibility is that positive cavities are not essential features of the solvents. That is, if they can occur, they may be utilized provided the energetics are favorable but, if they do not occur, the electron may still be accomodated elsewhere.

The location of the maximum in the rubidium spectra, near 9000 Å, and the small peak in the cesium spectrum in 1 of the solvents is reminiscent of 2 cases discussed by Fowles *et al.*[9] These men noted that relatively concentrated solutions of potassium in methylamine and in propylene diamine display a small absorption maximum at 8500 Å. It may be that

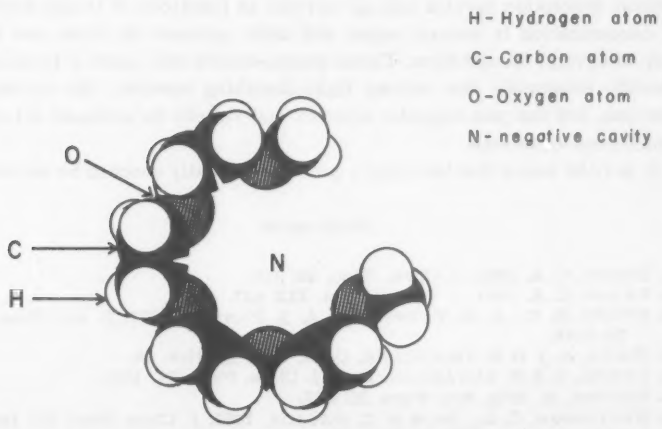

FIGURE 2. Cavity model of bis [2-(2-methoxyethoxy) ethyl] ether.

this peak in the 4 cases noted thus far corresponds to a third spectroscopically visible species.

The fact that sodium alone is insoluble, but that it dissolves in the presence of potassium, suggests that the potassium may create cavities in the solvent that the sodium, because of its higher ionization potential, is unable readily to cause. At any rate, it is a further evidence of the importance of the nature of the metal, and therefore militates against the simple cavity picture.

It would appear, then, that the most general model of solutions of alkali metals in various solvents requires a combination of the two leading theories with the additional postulate of a diamagnetic, conducting species. The monomer, dimer, and the various ion pairs can be used to interpret the concentration dependence of electric conductance and magnetic susceptibility. The specific interaction between electron and cation implied by these species is needed to account for the variation in properties from metal to metal and by the nmr results. Thus, the solution may contain any or all of the species M^+, e^-, M^+e^- (monomer), $M_2^{++}e_2^{--}$ (dimer), e^-, e_2^{--} and $M^+e_2^{--}$. The geometrical requirements for a satisfactory solvent include the possibility of forming a negative cavity and, perhaps, a positive one as well. The solvent must be polar enough for the solvation energy of the cation to stabilize the cavity, but not so polar as to displace hydrogen by the metal. Oxygen in ether linkages and nitrogen in amines (and perhaps phosphorous in phosphines) have about the right electronegativity for this.

Detailed understanding of the various equilibria involved will require the estimation of the binding and solvation energies of the various species listed above. Careful quantitative determinations of electric conductivity, optical absorption spectra and epr spectra as functions of temperature and of concentration in several amine and ether systems are even now under way in several laboratories. These measurements will make it possible to identify separately the various light-absorbing species, the conducting species, and the paramagnetic species and thereby to evaluate all of the equilibrium constants.

It is to be hoped that this knotty problem is finally about to be unraveled.

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SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

SUPERIOR MEDICINALS ACHIEVED BY SIMPLE CHEMICAL MODIFICATION*

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INTRODUCTION

In the search for more effective medicinals too little attention is given to the simple modification of the physical and chemical properties of compounds already known. The medicinal chemist's usual aim is to synthesize a unique structure that he expects will possess qualities superior to known drugs. The newly discovered natural product or synthetic compound is marketed as the parent compound, mineral acid salt, or alkali metal salt. No attempt seems to have been made by the inventor to determine whether the marketed form of the drug is optimal for therapy. Such a practice is difficult to understand when one is familiar with the significant improvements that have been made in drug action by simple modifications in physical properties achieved by salt formation and esterification. Perhaps this collection of a few examples of drugs "tailor-made" for superior performance will serve to focus attention on an infrequently considered area of medicinal research.

METHODS USED TO MODIFY DRUGS

Esterification

Salicylates. For many years it has been known that salicylic acid produces marked antipyretic and analgesic effects and also gives striking relief of the phenomena of acute articular rheumatism.[1] Since salicylic acid is an active irritant, it is not surprising to find that undesirable gastric symptoms follow the oral administration of this chemical to humans. The desire to avoid these undesirable side effects led to the introduction of various salts and esters. Thus, sodium salicylate administered with an equal quantity of sodium bicarbonate is tolerated much better. In 1899 Dreser[2] introduced acetylsalicylic acid (aspirin). He reasoned that the corrosive action of salicylic acid would be obviated by acetylation of the phenolic hydroxyl and that hydrolysis in the intestine would release the parent compound for absorption. Later work has shown that aspirin still produces some gastric irritation and is absorbed partially unchanged.[3] Today aspirin is still the most widely used salicylate form.

*This paper, illustrated with slides, was presented at a meeting of the Section on January 12, 1959.

*Triacetyloleandomycin (Tao).** Marked physical,[4] chemical[4] and biological changes[5-7] resulted from the acetylation of oleandomycin, a medium-spectrum antibiotic. This acetylated derivative has already gained more extensive medical use than the parent compound.[8] Tao is much less soluble in water. Its insolubility in water has simplified the formulation of palatable and stable aqueous suspensions for oral use. Tao is capable of producing much higher antibiotic levels in body fluids following oral administration to human subjects.[9]

Chloromycetin. The bitter taste of Chloromycetin made the preparation of aqueous formulations for oral use exceedingly difficult. The synthesis of Chloromycetin palmitate overcame this obstacle.[10] Palatable aqueous suspensions were easily prepared with this much less soluble ester. Although hydrolysis by duodenal contents was required before efficient oral absorption could occur, antibiotic blood levels were quite comparable with the parent compound.[11]

Salt Formation

Quinidine. Nausea frequently occurs after the oral administration of quinidine sulfate. This irritating property of quinidine has complicated its use in the treatment of auricular fibrillation. The polygalacturonate of quinidine significantly corrects this objectionable side effect.[12] Polygalacturonic acid, a constituent of pectin, has been used for years in alleviating irritation of the intestinal tract.

Thiamine. The marked diminution in solubility achieved by conversion of thiamine to its dicetylsulfate salt accounts for its superior stability in aqueous media at various *p*Hs.[13] Thiamine dicetylsulfate is odorless, tasteless, nonhydroscopic, and more stable than the more soluble forms of thiamine, even in the dry state. The toxicity on a molar basis is similar to that of thiamine chloride hydrochloride. Blood levels are more sustained after administration of the dicetylsulfate salt.[14]

Benzylpenicillin (penicillin G). Two serious drawbacks were encountered with the parenteral use of sodium penicillin G. Not only were multiple daily injections required to maintain therapeutic blood levels, but pain was also encountered at the site of injection. The concomitant use of a local anesthetic to alleviate this pain resulted in the discovery of the procaine salt of penicillin G.[15] This crystalline salt shows a water solubility of roughly 5 to 7 mg./ml. The intramuscular administration of 1 cc. of an aqueous suspension containing 300,000 units (300 mg.) is very well tolerated and yields therapeutic blood levels for 24 hours.[16] The suspension of the same quantity of this finely subdivided salt in peanut oil containing 2 per cent aluminum monostearate yields therapeutic blood levels for 96 hours.[17] The di-penicillin G salt of *N,N'*-dibenzyl-

*The trade name of the J. B. Roerig and Company, Division, Chas. Pfizer & Co., Inc., for triacetyloleandomycin is Tao.

ethylenediamine (benzathine) is even more insoluble than the procaine salt. The intramuscular administration of 300,000 units of this salt of penicillin G suspended in water will produce subtherapeutic blood levels beyond 96 hours.[18] The preparation of liquid formulations for oral use was complicated by the instability of penicillin G. The highly insoluble benzathine salt made it possible to prepare stable and palatable aqueous suspensions for oral use. Therapeutic blood levels were achievable after the oral administration of benzathine penicillin G.[19]

Phenoxymethylpenicillin (penicillin V). Phenoxymethylpenicillin is more stable than benzylpenicillin at low *p*Hs; it also affords higher blood levels after oral administration.[20] A study of the dissolution rates and water solubility of various salts of penicillin V showed that a direct correlation exists between solubility, rate of dissolution, and blood levels obtained after oral administration.[21] This careful study prompted manufacturers of penicillin V in the United States to use the potassium salt of this antibiotic in place of the free acid originally marketed.

Streptomycin. Conversion of the ordinary salts of streptomycin to macromolecular salts causes significant changes in blood and lymph levels.[22] Polyacrylic acid, sulfonic or phosphorylated polysaccharides, and a series of polyuronic substances have been used as the acids for preparing these macromolecular salts of streptomycin. The parenteral administration of these unique compounds produces very low blood levels that are maintained for a much longer period of time. The lymph levels, however, are very high and the acute toxicity of such compounds is significantly lower than the more conventional salts of streptomycin.

Morphine. The analgesic potencies of a series of equimolar concentrations of morphine salts were compared in rats (parenteral administration). The tartrate was found to be more effective than the sulfate and the hydrochloride. In addition, these same salts and the meconate were tested for their efficacy in depressing the respiratory rate in chloralosed dogs. Here again, the tartrate was most effective.[23]

Epinephrine. Epinephrine tartrate showed the greatest pressor response of a series of epinephrine salts administered intraveneously to spinal cats.[23]

Strychnine. The comparative convulsive actions of different salts of strychnine were compared in frogs. Strychnine citrate and tartrate produced almost similar percentages of response and intensities of hyperreflexia in frogs. The onset of convulsion was, however, more prompt with the hydrochloride, and the duration of action greater after the tartrate salt.[23]

Resin Adsorption

Vitamin B_{12}. Radioactive vitamin B_{12} (Co^{60}) was orally administered in aqueous solution or as an ion-exchange resin adsorbate (XE-64)* to

*The XE-64 resin adsorbate of vitamin B_{12} is marketed by Chas. Pfizer & Co., Inc., Brooklyn, N. Y. under the trade name Stablets.

a series of 30 human volunteers. Intramuscular injection of 1000 μg. of unlabeled vitamin B_{12} was administered to flush out any absorbed tagged vitamin B_{12}. Those patients receiving the solution showed an average 24-hour urinary radioactivity of 560±31.8 mμg. Those receiving the resin adsorbate showed a concentration of 1147±113.4 mμg.[24]. Thus it can be seen that the use of an ion-exchange resin as a carrier for vitamin B_{12} enables one to achieve more efficient oral absorption. The adsorbate of vitamin B_{12} also shows better stability in multicomponent dry formulations than does crystalline vitamin B_{12}.

Codeine. The duration of codeine analgesia in the rat was extended when it was administered as a resin adsorbate. The sulfonic acid cation exchangers Amberlite IR-120 and XE-69 were used.[25]

Chelation

Terramycin. The local irritation caused by the intramuscular administration of Terramycin hydrochloride was completely eradicated by the simultaneous administration of magnesium chloride. The presence of the magnesium ion at the site of injection ensured complete absorption and absolute freedom from irritation. Terramycin is known to chelate metallic ions. It is felt that those functional groups in the molecule that are concerned with the chelation processes are the very same groups that are apt to cause the local irritation observed in the absence of metal. Calcium diterramycin is highly insoluble in water. More stable and more palatable aqueous suspensions for oral use can be prepared with the use of this material.[26]

Tetracycline. A local irritation caused by tetracycline upon intramuscular administration was significantly mitigated by the simultaneous administration of magnesium chloride. The magnesium chelate of tetracycline is obtained as a water-insoluble crystalline compound. Its insolubility greatly simplifies the formulation of palatable and stable aqueous suspensions for oral use.[26]

Conclusion

The above examples serve to illustrate how better toleration, better absorption, increased stability, increased palatability, and more sustained therapeutic response after oral and parenteral administration can be achieved by the simple chemical modification of medicinals.

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DIVISION OF ENGINEERING

OPTIMUM LENGTH OF A ROCKET-WALL EXTENSION BEYOND ITS CIRCUMFERENTIAL KEYWAY*

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Introduction

One of the common closure arrangements found in rocket design is shown diagrammatically in FIGURE 1. The outside diameter of the rocket is constant and the wall thickness remains uniform for a considerable length of the unit. A short distance from the end, however, the cylinder is recessed to accommodate a circumferential key that connects the rocket wall to an end closure that maintains internal pressure within the assembly.

The relatively short section of the rocket wall that extends beyond the keyway serves primarily to retain the key but, in addition, it makes some contribution to the stiffness of the structure. The exact contribution obviously depends on the length of the extension, with longer sections contributing greater stiffness. One may expect, however, that there exists some optimum length beyond which there results very little increase in the length of the extension. Since weight savings are an important consideration in rocket design, the current study was conducted with the objective of determining the optimum distance from the keyway to the edge of the vessel, so that maximum stiffness is developed at the recessed section while utilizing a minimum amount of material.

The study of the rocket-wall problem is based on discontinuity theory. According to this theory, a structure under investigation is hypothetically separated into a number of free bodies at sections where discontinuity of loading, material, or cross section is present. Each of the resulting free bodies is then studied under the influence of the externally applied

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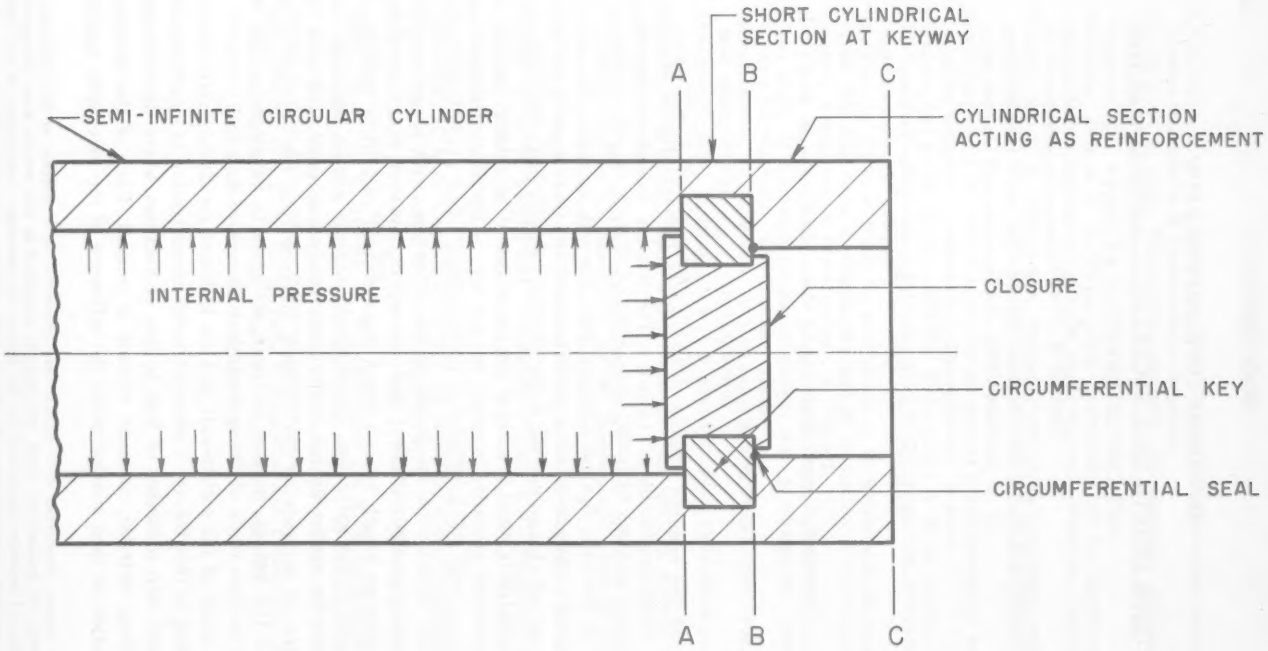

FIGURE 1. The circular semi-infinite rocket wall containing a circumferential keyway. Not drawn to scale.

loads, as well as the resultant bending moments, shear forces, and tensile forces that must be introduced to represent the stress system as it existed before the original structure was subdivided. The resultant moments and forces appear initially as unknown quantities, but may be evaluated subsequently by imposing the requirement of continuity of deformation at the junctions.

In most rockets, the wall thickness is sufficiently small in comparison to its mean radius to make possible the use of shell theory in analyzing each of the free bodies. Shell theory was also applicable in analyzing sections of other composite structures previously studied by Watts and Lang,[1] Watts and Burrows,[2] McCalley and Kelly,[3] and Horvay and Clausen,[4,5] to name a few. In each case these investigators also employed discontinuity techniques.

Although solutions to shell theory problems appear in the literature, they are not always complete, nor are they in a form suitable for the present study. Consequently, in order to present the rocket study from a unified and consistent point of view, the solutions to the general problem of deformation of a thin-walled circular cylinder subjected to an arbitrary system of axially symmetrical forces is included in this paper. Since the solution to the general problem contains parameters that are complicated functions of the geometry, tables of these constants are included.

Analysis of a Short Circular Cylinder

FIGURE 2 shows a cylinder of length ℓ, subjected to internal pressure p, axial tensile forces H and T, bending moments M_R and M_L, and shearing forces Q_R and Q_L, all defined positive as shown. The foregoing moments and forces are loads per unit length, and are assumed to be uniformly distributed around the circumference; the subscripts R and L refer to the right and left edges of the cylinder, respectively. The positive directions were chosen as shown in FIGURE 2, so that the same sign convention may be used for two adjacent bodies, thus permitting simple and systematic writing of continuity equations at the surface of separation.

Two axial forces, H and T, are shown acting on the section to distinguish two different effects. The axial force H is caused by the internal pressure within the cylinder, while T is the axial force induced by any external system of loads. If the cylinder is closed at both ends and subjected to internal pressure p, the resultant force on the end closure is transmitted through the cylinder as an axial force H equal to $pR/2$. Should the cylinder not be closed at both ends, H is obviously zero. Since T depends on an external system of loads, its magnitude depends on the application.

FIGURE 3 shows the sign conventions selected for the deformations at the end of the cylinder. The radial displacement w is taken positive at either end when it is radially inward. Rotation θ_L at the left end of the

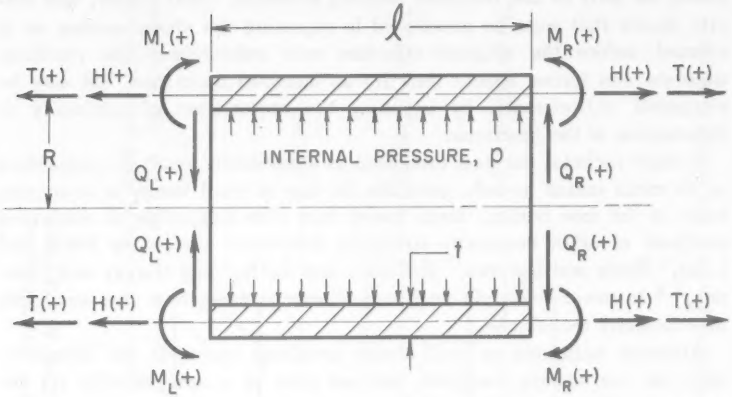

FIGURE 2. The sign convention for the forces on a short circular cylinder.

cylinder is taken as positive if it is toward the axis, while rotation θ_R at the right end of the cylinder is taken positive if it is away from its axis.

It can be shown[6] that when H and T are equal to zero, the radial displacement w of the circular cylinder shown in FIGURE 2 satisfies the differential equation

$$d^4w/dx^4 + 4\beta^4 w = -p/D \tag{1}$$

where

$$\beta^4 = 3(1 - \mu^2)/R^2t^2; \quad D = Et^3/12\,(1 - \mu^2) \tag{2}$$

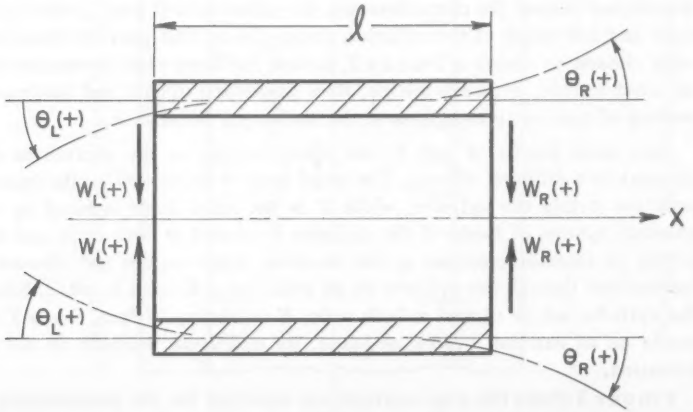

FIGURE 3. The sign convention for the deformation of a short circular cylinder.

and p denotes the internal pressure, E is the modulus of elasticity, μ is Poisson's ratio, R is the mean radius, and t is the wall thickness of the cylinder. D is usually referred to as the flexural rigidity.

The solution to EQUATION 1 may be expressed as

$$w = e^{\beta x}(C_1 \cos \beta x + C_2 \sin \beta x) + e^{-\beta x}(C_3 \cos \beta x + C_4 \sin \beta x) - R^2 p/Et \quad (3)$$

The four constants C_1, C_2, C_3, and C_4 may be evaluated in the terms of the bending moments and shearing forces that exist at the ends of the cylinder by using the relations between the radial displacement w and the forces on the boundary, namely

$$\begin{aligned} [M_x]_{x=0} &= -D[d^2w/dx^2]_{x=0} = M_L\,; \; [Q_x]_{x=0} = -D[d^3w/dx^3]_{x=0} = -Q_L \\ [M_x]_{x=\ell} &= -D[d^2w/dx^2]_{x=\ell} = M_R\,; \; [Q_x]_{x=\ell} = -D[d^3w/dx^3]_{x=\ell} = -Q_R \end{aligned} \quad (4)$$

Application of these expressions to EQUATION 3 leads to the following equations for deflection w and rotation $\theta = dw/dx$ at the left and right edges of the cylinder:

$$\theta_L = -(S/2\beta D)M_L + (B/2\beta^2 D)Q_L + (Y/2\beta D)M_R + (K/2\beta^2 D)Q_R \quad (5)$$

$$w_L = -(B/2\beta^2 D)M_L + (L/2\beta^3 D)Q_L + (K/2\beta^2 D)M_R + V/2\beta^3 D)Q_R - pR^2/Et \quad (6)$$

$$\theta_R = -(Y/2\beta D)M_L + (K/2\beta^2 D)Q_L + (S/2\beta D)M_R + (B/2\beta^2 D)Q_R \quad (7)$$

$$w_R = (K/2\beta^2 D)M_L - (V/2\beta^3 D)Q_L - (B/2\beta^2 D)M_R - (L/2\beta^3 D)Q_R - pR^2/Et \quad (8)$$

where the parameters K, B, S, Y, L and V* are defined as follows:

$$\begin{aligned} (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)K &= 2 \sin \beta\ell \; \text{Sinh} \; \beta\ell \\ (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)B &= \text{Sinh}^2 \beta\ell + \sin^2 \beta\ell \\ (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)S &= 2 \sin \beta\ell \cos \beta\ell + 2 \; \text{Sinh} \; \beta\ell \; \text{Cosh} \; \beta\ell \\ (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)Y &= 2 \sin \beta\ell \; \text{Cosh} \; \beta\ell + 2 \cos \beta\ell \; \text{Sinh} \; \beta\ell \\ (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)L &= \text{Sinh} \; \beta\ell \; \text{Cosh} \; \beta\ell - \sin \beta\ell \cos \beta\ell \\ (\text{Sinh}^2 \beta\ell - \sin^2 \beta\ell)V &= \sin \beta\ell \; \text{Cosh} \; \beta\ell - \cos \beta\ell \; \text{Sinh} \; \beta\ell \end{aligned} \quad (9)$$

*The scientific staff of M. W. Kellogg Company is responsible for the original definition of these parameters and for the preparation of TABLE 1. Their original work appears in an unpublished report.[7]

These terms act as influence coefficients for the cylinder. For convenience, their numerical values are given in TABLE 1 for values of $\beta\ell$ from 0.5 to 5.0.

TABLE 1

$\beta\ell$	K	B	S	Y	L	V
0.50	12.00	12.00	46.60	46.10	4.00	2.000
0.60	8.31	8.37	27.70	27.10	3.33	1.670
0.70	6.09	6.17	18.10	17.40	2.87	1.430
0.80	4.65	4.76	12.40	11.60	2.51	1.240
0.90	3.65	3.78	8.89	7.99	2.23	1.100
1.00	2.94	3.10	6.74	5.75	2.02	0.986
1.10	2.41	2.61	5.32	4.23	1.85	0.890
1.20	1.99	2.23	4.35	3.17	1.70	0.809
1.30	1.68	1.95	3.69	2.41	1.58	0.738
1.40	1.41	1.73	3.22	1.84	1.48	0.676
1.50	1.20	1.56	2.87	1.41	1.39	0.621
1.60	1.02	1.43	2.61	1.08	1.32	0.570
1.70	0.875	1.33	2.44	0.821	1.27	0.523
1.80	0.745	1.24	2.31	0.616	1.21	0.480
1.90	0.632	1.18	2.22	0.445	1.17	0.438
2.00	0.535	1.13	2.15	0.310	1.14	0.400
2.10	0.450	1.10	2.10	0.201	1.11	0.363
2.20	0.375	1.07	2.07	0.111	1.09	0.329
2.30	0.309	1.05	2.05	0.0392	1.07	0.296
2.40	0.251	1.03	2.03	−0.0188	1.05	0.265
2.50	0.200	1.02	2.02	−0.0649	1.04	0.235
2.60	0.155	1.01	2.01	−0.101	1.03	0.207
2.70	0.116	1.01	2.01	−0.128	1.02	0.181
2.80	0.0819	1.00	2.01	−0.148	1.01	0.157
2.90	0.0529	1.00	2.01	−0.161	1.01	0.134
3.00	0.0282	1.00	2.01	−0.169	1.01	0.113
3.10	0.00751	1.00	2.01	−0.173	1.00	0.0940
3.20	−0.00953	1.00	2.01	−0.173	1.00	0.0767
3.30	−0.0233	1.00	2.01	−0.169	1.00	0.0613
3.40	−0.0342	1.00	2.01	−0.163	1.00	0.0475
3.50	−0.0424	1.00	2.01	−0.156	1.00	0.0354
3.60	−0.0484	1.00	2.01	−0.147	1.00	0.0248
3.70	−0.0525	1.00	2.01	−0.137	1.00	0.0157
3.80	−0.0548	1.00	2.01	−0.126	1.00	0.00800
3.90	−0.0558	1.00	2.01	−0.115	1.00	0.00152
4.00	−0.0555	1.00	2.00	−0.103	1.00	−0.00380
4.10	−0.0543	1.00	2.00	−0.0925	1.00	−0.00809
4.20	−0.0523	1.00	2.00	−0.0818	1.00	−0.0115
4.30	−0.0498	1.00	2.00	−0.0716	1.00	−0.0140
4.40	−0.0468	1.00	2.00	−0.0619	1.00	−0.0158
4.50	−0.0435	1.00	2.00	−0.0528	1.00	−0.0171
4.60	−0.0400	1.00	2.00	−0.0445	1.00	−0.0177
4.70	−0.0364	1.00	2.00	−0.0369	1.00	−0.0180
4.80	−0.0328	1.00	2.00	−0.0299	1.00	−0.0178
4.90	−0.0293	1.00	2.00	−0.0237	1.00	−0.0174
5.00	−0.0259	1.00	2.00	−0.0182	1.00	−0.0167

If, on the other hand, the axial forces H and T have nonzero values, an additional radial deflection occurs due to the Poisson effect and is given by

$$w = \mu HR/Et + \mu TR/Et \tag{10}$$

Thus, for a pressurized vessel with closed ends, the deflections at the ends of the cylinder may be found by substituting EQUATIONS 10 and $H = pR/2$ into EQUATIONS 6 and 8, to obtain

$$w_L = -\frac{B}{2\beta^2 D} M_L + \frac{L}{2\beta^3 D} Q_L + \frac{K}{2\beta^2 D} M_R + \frac{}{2\beta^3 D} Q_R$$
$$-(1 - \frac{\mu}{2}) \frac{pR^2}{Et} + \frac{\mu TR}{Et} \tag{11}$$

$$w_R = \frac{K}{2\beta^2 D} M_L - \frac{V}{2\beta^3 D} Q_L - \frac{B}{2\beta^2 D} M_R - \frac{L}{2\beta^3 D} Q_R$$
$$-(1 - \frac{\mu}{2}) \frac{pR^2}{Et} + \frac{\mu TR}{Et} \tag{12}$$

The corresponding rotations, as given in EQUATIONS 5 and 7, remain unaltered.

In numerical computations based on the foregoing deformation equations, it is convenient to combine the parameters defined in EQUATIONS 2 in the following manner:

$$\beta D = Et^2/a\rho^{1/2}; \quad 2\beta D = Et^2/b\rho^{1/2}$$
$$2\beta^2 D = Et/c\rho; \quad 2\beta^3 D = E/d\rho^{3/2} \tag{13}$$

where

$$\rho = R/t \tag{14}$$

$$[3(1 - \mu^2)]^{1/4} a = 12(1 - \mu^2); \qquad [3(1 - \mu^2)]^{1/2} c = 6(1 - \mu^2)$$
$$[3(1 - \mu^2)]^{1/4} b = 6(1 - \mu^2); \qquad [3(1 - \mu^2)]^{3/4} d = 6(1 - \mu^2) \tag{15}$$

The expressions for a, b, c and d are functions of only Poisson's ratio μ, and hence may be treated as constants in most problems. For convenience, their values, as well as the coefficient $(1 - \mu/2)$, are presented in TABLE 2 for a range of μ from 0.25 to 0.50.

After introducing EQUATIONS 13 into EQUATIONS 5, 11, 7, and 12, the deformation equations may be rewritten in terms of the newly defined dimensionless quantities, to read

$$\theta_L = -bS\frac{\rho^{1/2}}{Et^2}M_L + cB\frac{\rho}{Et}Q_L + bY\frac{\rho^{1/2}}{Et^2}M_R + cK\frac{\rho}{Et}Q_R \qquad (16)$$

$$w_L = -cB\frac{\rho}{Et}M_L + dL\frac{\rho^{3/2}}{E}Q_L + cK\frac{\rho}{Et}M_R + dV\frac{\rho^{3/2}}{E}Q_R - (1-\frac{\mu}{2})\frac{pR^2}{Et} + \frac{\mu TR}{Et} \qquad (17)$$

$$\theta_R = -bY\frac{\rho^{1/2}}{Et^2}M_L + cK\frac{\rho}{Et}Q_L + bS\frac{\rho^{1/2}}{Et^2}M_R + cB\frac{\rho}{Et}Q_R \qquad (18)$$

$$w_R = cK\frac{\rho}{Et}M_L - dV\frac{\rho^{3/2}}{E}Q_L - cB\frac{\rho}{Et}M_R - dL\frac{\rho^{3/2}}{E}Q_R - (1-\frac{\mu}{2})\frac{pR^2}{Et} + \frac{\mu TR}{Et} \qquad (19)$$

The equations mathematically represent the deflections and rotations at the ends of a circular cylinder subject to axially symmetrical loading. Two special cases are of particular interest in the analysis to follow. These are the limiting cases when $\beta\ell \to 0$ and when $\beta\ell \to \infty$. As $\beta\ell \to 0$, a cylinder becomes sufficiently short so that, under load, there is essentially no difference in the rotation of the two ends. This limiting case is called the circular ring. The second case, termed the semi-infinite cylinder, is evolved when $\beta\ell \to \infty$. In this case the cylinder is so long that a load applied at one end has no appreciable effect on the deformation at the other end. These special cases are considered in the next two sections.

The Circular Cylindrical Ring

In the previous section, expressions were developed for deflections and rotations at the ends of a short circular cylinder subjected to an arbitrary system of loads. These expressions were written in terms of the influence coefficients K, B, S, Y, L, and V described in EQUATIONS 9. Expansion in series form of the trigonometric and hyperbolic functions used to describe the influence coefficients permits the rewriting of EQUATIONS 9 as

$$K = \frac{3}{(\beta\ell)^2}\left[1 - \frac{1}{90}(\beta\ell)^4 + \ldots\right]; \quad Y = \frac{6}{(\beta\ell)^3}\left[1 - \frac{1}{30}(\beta\ell)^4 + \ldots\right]$$

$$B = \frac{3}{(\beta\ell)^2}\left[1 + \frac{2}{45}(\beta\ell)^4 + \ldots\right]; \quad L = \frac{2}{\beta\ell}\left[1 + \frac{2}{105}(\beta\ell)^4 + \ldots\right] \qquad (20)$$

$$S = \frac{6}{(\beta\ell)^3}\left[1 + \frac{2}{15}(\beta\ell)^4 + \ldots\right]; \quad V = \frac{1}{\beta\ell}\left[1 - \frac{1}{210}(\beta\ell)^4 + \ldots\right]$$

For small values of $\beta\ell$ the terms of higher order may be neglected, and the influence coefficients become simply

$$K = B = \frac{3}{(\beta\ell)^2}\ ;\ S = Y = \frac{6}{(\beta\ell)^3}\ ;\ L = \frac{2}{\beta\ell}\ ;\ V = \frac{1}{\beta\ell} \qquad (21)$$

Comparison of EQUATIONS 20 and 21 shows that it is reasonable to drop the terms of higher order whenever $\beta\ell < 0.5$, since the error introduced in the numerical values of the influence coefficients is then very small.

It may thus be concluded that, when the value of the parameter $\beta\ell$ for a circular cylinder is less than 0.5, its influence coefficients may be evaluated from EQUATIONS 21. A cylinder of this type may then be called a circular cylindrical ring. The deformations of the ring are still given by EQUATIONS 16, 17, 18, and 19.

TABLE 2

μ	a	b	c	d	$(1-\frac{\mu}{2})$
0.25	8.6873	4.3437	3.3542	2.5901	0.875
0.26	8.6514	4.3257	3.3449	2.5864	0.870
0.27	8.6148	4.3074	3.3355	2.5828	0.865
0.28	8.5763	4.2882	3.3255	2.5789	0.860
0.29	8.5365	4.2683	3.3153	2.5749	0.855
0.30	8.4981	4.2490	3.3066	2.5732	0.850
0.31	8.4529	4.2265	3.2935	2.5667	0.845
0.32	8.4084	4.2042	3.2819	2.5620	0.840
0.33	8.3626	4.1813	3.2701	2.5573	0.835
0.34	8.3153	4.1577	3.2577	2.5524	0.830
0.35	8.2666	4.1333	3.2450	2.5475	0.825
0.36	8.2165	4.1083	3.2319	2.5424	0.820
0.37	8.1649	4.0825	3.2183	2.5372	0.815
0.38	8.1119	4.0560	3.2043	2.5316	0.810
0.39	8.0567	4.0284	3.1898	2.5258	0.805
0.40	8.0006	4.0003	3.1750	2.5200	0.800
0.41	7.9424	3.9712	3.1595	2.5137	0.795
0.42	7.8826	3.9413	3.1437	2.5074	0.790
0.43	7.8218	3.9109	3.1276	2.5011	0.785
0.44	7.7588	3.8794	3.1107	2.4941	0.780
0.45	7.6948	3.8474	3.0935	2.4873	0.775
0.46	7.6291	3.8146	3.0759	2.4804	0.770
0.47	7.5616	3.7808	3.0577	2.4731	0.765
0.48	7.4918	3.7459	3.0389	2.4652	0.760
0.49	7.4209	3.7105	3.0195	2.4572	0.755
0.50	7.3487	3.6744	3.0000	2.4495	0.750

The Semi-Infinite Circular Cylinder

Another special case of the short circular cylinder that is of considerable importance in practical problems is the semi-infinite cylinder. It may be observed by examining EQUATIONS 9 that, as $\beta\ell$ increases indefinitely, the influence coefficients approach the following limiting values:

$$\begin{gathered}\lim_{\beta\ell\to\infty} K = 0; \quad \lim_{\beta\ell\to\infty} S = 2.00; \quad \lim_{\beta\ell\to\infty} L = 1.00 \\ \lim_{\beta\ell\to\infty} B = 1.00; \quad \lim_{\beta\ell\to\infty} Y = 0; \quad \lim_{\beta\ell\to\infty} V = 0\end{gathered} \tag{22}$$

A comparison of the values of the influence coefficients as given by EQUATIONS 22 with those listed in TABLE 1 indicates that the limiting values may be used in the practical analysis of cylinders whenever $\beta\ell > 5.0$ without introducing appreciable error.

The deflection and rotation at the right edge of a pressurized semi-infinite cylinder loaded at the right edge with bending moment, shear, and axial load are given by EQUATIONS 19 and 18 with influence coefficients defined in EQUATIONS 22. Thus

$$w_R = -c\frac{\rho}{Et}M_R - d\frac{\rho^{3/2}}{E}Q_R - (1-\frac{\mu}{2})\frac{pR^2}{Et} + \frac{\mu TR}{Et} \tag{23a}$$

$$\theta_R = a\frac{\rho^{1/2}}{Et^2}M_R + c\frac{\rho}{Et}Q_R \tag{23b}$$

Similarly, in view of EQUATIONS 17, 16, and 22, the deformations at the left edge of a semi-infinite cylinder due to loads at the corresponding edge are given by

$$w_L = -c\frac{\rho}{Et}M_L + d\frac{\rho^{3/2}}{E}Q_L - (1-\frac{\mu}{2})\frac{pR^2}{Et} + \frac{\mu TR}{Et} \tag{24a}$$

$$\theta_L = -a\frac{\rho^{1/2}}{Et^2}M_L + c\frac{\rho}{Et}Q_L \tag{24b}$$

The coefficients ρ, a, b, c, and d retain their original definitions given in EQUATIONS 14 and 15.

In summary, then, the analysis of deflections and rotations of all thin-walled, circular cylinders subjected to axially symmetrical loads may be placed into one of the following three categories:

(1) If $0 < \beta\ell < 0.5$ for a given cylinder, it may be treated as a circular cylindrical ring. The simplified coefficients given in EQUATIONS 21 may

then be used in conjunction with EQUATIONS 16, 17, 18, and 19 to obtain the deflections and rotations.

(2) If, however, for a given cylinder, $0.5 \leq \beta\ell \leq 5.0$, then EQUATIONS 16, 17, 18, and 19 still apply, but the influence coefficients are defined in EQUATIONS 19 and are listed in TABLE 1.

(3) For relatively long cylinders, $\beta\ell > 5.0$, one may use the semi-infinite cylinder approximation with reasonable accuracy. In this case, the deflections and rotations may be calculated by using EQUATIONS 23 or 24.

Analysis of the Recessed, Semi-Infinite Cylinder

Consider the problem of the cylinder recessed to retain a circumferential key as shown in FIGURE 1. To study the effect of the length of the wall that extends beyond the keyway on the stiffness of the structure, it is desirable to express the deformation at Section *B-B* in terms of the other parameters of the cylinder, since this deformation may be used as a convenient measure of stiffness.

The effect of internal pressure acting on the end closure is included in the deformation study by introducing a force per unit length F equal to the resultant force on the closure and uniformly distributed around the keyway. The rocket may then be analyzed as a recessed circular cylinder under the influence of the force F and the internal pressure p.

In conformity with discontinuity theory, one may hypothetically divide the recessed circular cylinder at Sections *A-A* and *B-B* into three free bodies, as shown in FIGURE 4. Free Body 1 is of wall thickness t_1 and is considered long enough so that it may be analyzed as a semi-infinite cylinder. Free Body 2 is of wall thickness t_2 and length ℓ_2, whereas free body 3 is of wall thickness t_3 and length ℓ_3. In the most general case, free bodies 2 and 3 may be analyzed as short cylinders, but in practice they are often short enough to be analyzed as circular cylindrical rings.

In general, the mean radii of the three free bodies are not equal. Assuming them equal, however, is useful in reducing the number of parameters encountered in the problem. This assumption does not introduce appreciable error as long as the ratios of wall thicknesses to the mean radii are sufficiently small for shell theory to apply. Assuming equal mean radii does not imply, however, that the eccentricity between the center lines of adjacent bodies may be neglected when the effect of axial forces is considered. Even small eccentricities will induce modest bending moments for axial forces of reasonable magnitude.

FIGURE 4 shows each of the free bodies that make up the composite vessel, subjected to the applied loads such as pressure p and axial force F, as well as to the axial force H, shear force Q, and bending moment M.

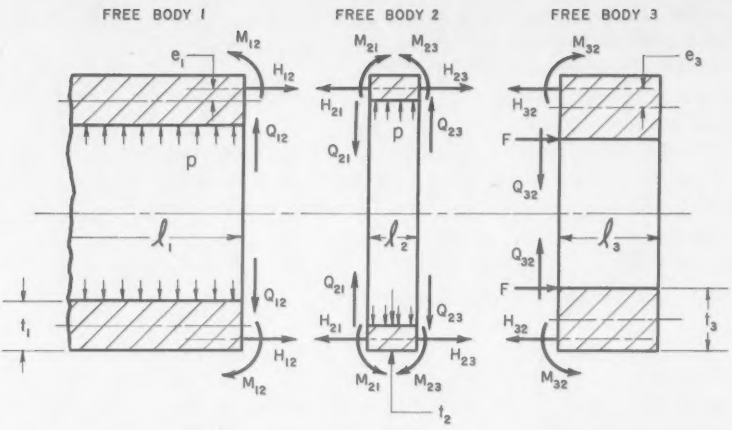

FIGURE 4. The free body diagrams of the recessed circular cylinder.

The resultant loads H, Q, and M represent the stress system that existed at Sections *A-A* and *B-B* before the hypothetical cuts were made. The action of internal pressure in the axial direction at Sections *A-A* and *B-B* is not shown, however, since its effect is negligible and its introduction serves to unduly lengthen the over-all analysis. In order to distinguish the forces acting on Free Body 1 from those acting on Free Body 2, a double subscript notation is used; the subscript ij indicates a force or moment on Free Body i due to Free Body j.

It should be noted that the axial forces H_{21} and H_{23} are chosen to act at the mean radius of Free Body 2. Thus, the corresponding forces H_{12} and H_{32} are eccentrically located with respect to the mean radii of free bodies 1 and 3 by distances e_1 and e_3, respectively, where

$$e_1 = (t_1 - t_2)/2\,; \tag{25a}$$

$$e_3 = (t_3 - t_2)/2 \tag{25b}$$

All forces and moments in FIGURE 4 are shown so as to correspond with the sign convention previously established. Their actual directions will be indicated, of course, by the sign of the values obtained in the solution to the problem.

As discussed earlier, the resultant forces and bending moments at each junction initially are unknown quantities, but can be evaluated from continuity considerations. The associated set of equations may be found by application of the previously derived deformation equations to each of the free bodies.

As shown in FIGURE 4, the axial force $H_{12} = pR_1/2$, caused by the action of the internal pressure on the end closure, is not applied at the

mean radius of Free Body 1. This eccentric loading is due to the difference in the mean radii for the 2 adjacent bodies. Since the derivations presented in the previous sections were all based on the assumption that an axial force must pass through the mean radius of any cylinder, it is convenient to replace the eccentric load H_{12} by an equivalent system of loading, consisting of force $H'_{12} = H_{12}$ acting at the mean radius and a bending moment $m_{12} = H_{12}\, e_1$ applied to the proper direction to account for the moment of H_{12} about the axis at the mean radius. In view of EQUATIONS 25, the bending moment m_{12} may also be expressed as

$$m_{12} = \frac{pR_1 t_1}{4}(1 - r) \tag{26}$$

where $r = t_2/t_1$.

In the analysis of Free Body 1, it is convenient to combine the moment due to the eccentric axial load with the pure bending moment M_{12} and consider a net bending moment M'_{12} where

$$M'_{12} = M_{12} - m_{12} \tag{27}$$

The net moment M'_{12}, as well as the axial force H'_{12}, act at the mean radius of Free Body 1. The deformations of Free Body 1, when considered a semi-infinite cylinder, may then be described according to EQUATIONS 23 as

$$w_{12} = -c\frac{\rho}{Et_1} M'_{12} - d\frac{\rho^{3/2}}{E} Q_{12} - (1 - \frac{\mu}{2})\frac{pR_1^2}{Et_1} \tag{28a}$$

$$\theta_{12} = a\frac{\rho^{1/2}}{E} M'_{12} + c\frac{\rho}{ET_1} Q_{12} \tag{28b}$$

where

$$\rho = R_1/t_1 \tag{29}$$

and where force T in EQUATION 23 is zero since there is no external force acting on the cylinder. If the expressions for the bending moments given by EQUATIONS 26 and 27 are introduced into the deformations of EQUATIONS 28, they may be rewritten to read

$$w_{12} = -c\frac{\rho}{Et_1} M_{12} - d\frac{\rho^{3/2}}{E} Q_{12} + \frac{c}{4}\frac{p\rho}{E} R_1 (1 - r) - (1 - \frac{\mu}{2})\frac{pR_1^2}{Et_1} \tag{30a}$$

$$\theta_{12} = a\frac{\rho^{1/2}}{E} M_{12} + c\frac{\rho}{Et_1} Q_{12} - \frac{a}{4}\frac{p\rho R_1}{E}(1 - r) \tag{30b}$$

where bending moment M_{12}, of course, corresponds to the original one shown in FIGURE 4.

If one now multiplies the deflection equation by α and the rotation equation by γ where

$$\alpha = E/\rho^2 p t_1 \; ; \quad \gamma = E/\rho^{3/2} p \tag{31}$$

and if one introduces a new set of dimensionless ratios

$$Z_1 = \frac{M_{12}}{\rho p t_1^2} \; ; \qquad Z_2 = \frac{Q_{12}}{\rho^{1/2} p t_1} \; ; \qquad Z_3 = \frac{M_{23}}{\rho p t_1^2} ; \qquad Z_4 = \frac{Q_{23}}{\rho^{1/2} p t_1} \tag{32}$$

then EQUATIONS 30 may be written

$$\alpha w_{12} = -cZ_1 - dZ_2 + (c/4)(1-r) - (1-\mu/2) \tag{33a}$$

$$\gamma \theta_{12} = aZ_1 + cZ_2 - (a/4)(1-r) \tag{33b}$$

These expressions describe the deformation of Free Body 1 at Section *A-A*. They will be used later, together with similar sets of equations for free bodies 2 and 3.

The deformations of Free Body 2 are described in EQUATIONS 16, 17, 18, and 19 when the body is a short cylinder or circular cylindrical ring. When these equations are applied to Free Body 2, which has a thickness $t_2 = t_1$ and a mean radius R_1, one finds

$$\theta_{21} = -\frac{bS_2\rho^{1/2}}{Er^{5/2}t_1^2} M_{21} + \frac{cB_2\rho}{Er^2 t_1} Q_{21} + \frac{bY_2\rho^{1/2}}{Er^{5/2}t_1^2} M_{23} + \frac{cK_2\rho}{Er^2 t_1} Q_{23} \tag{34a}$$

$$w_{21} = -\frac{cB_2\rho}{Er^2 t_1} M_{21} + \frac{dL_2\rho^{3/2}}{Er^{3/2}} Q_{21} + \frac{cK_2\rho}{Er^2 t_1} M_{23} + \frac{dV_2\rho^{3/2}}{Er^{3/2}} Q_{23} - (1-\frac{\mu}{2}) \frac{pR_1^2}{Ert_1} \tag{34b}$$

$$\theta_{23} = -\frac{bY_2\rho^{1/2}}{Er^{5/2}t_1} M_{21} + \frac{cK_2\rho}{Er^2 t_1} Q_{21} + \frac{bS_2\rho^{1/2}}{Er^{5/2}t_1^2} M_{23} + \frac{CB_2\rho}{Er^2 t_1} Q_{23} \tag{34c}$$

$$w_{23} = \frac{cK_2\rho}{Er^2 t_1} M_{21} - \frac{dV_2\rho^{3/2}}{Er^{3/2}} Q_{21} - \frac{cB_2\rho}{Er^2 t_1} M_{23} - \frac{dK_2\rho^{3/2}}{Er^{3/2}} Q_{23} - (1-\frac{\mu}{2}) \frac{pR_1^2}{Ert_1} \tag{34d}$$

where ρ is defined in EQUATION 29 as before. The subscript 2 appearing with the influence coefficients K, B, S, Y, L, and V are used to distinguish them from another set of coefficients to be used when studying Free Body 3.

Again, by multiplying the deflection equations by α and the rotation equations by γ as defined in EQUATIONS 31 and by introducing the dimensionless ratios of EQUATIONS 32, one may write the deformations of EQUATIONS 34 as

$$\gamma\theta_{21} = -(bS_2/r^{5/2})\,Z_1 + (cB_2/r^2)\,Z_2 + (bY_2/r^{5/2})\,Z_3 + (cK_2/r^2)\,Z_4 \quad (35a)$$

$$\alpha w_{21} = -(cB_2/r^2)\,Z_1 + (dL_2/r^{3/2})\,Z_2 + (cK_2/r^2)\,Z_3 + (dV_2/r^{3/2})\,Z_4 - (1/r)\,(1-\mu/2) \quad (35b)$$

$$\gamma\theta_{23} = -(bY_2/r^{5/2})\,Z_1 - (cK_2/r^2)\,Z_2 + (bS_2/r^{5/2})\,Z_3 + (cB_2/r^2)\,Z_4 \quad (35c)$$

$$\alpha w_{23} = (cK_2/r^2)\,Z_1 - (dV_2/r^{3/2})\,Z_2 + (cB_2/r^2)\,Z_3 - (dL_2/r^{3/2})\,Z_4 - (1/r)\,(1-\mu/2) \quad (35d)$$

Analyzing Free Body 3, one notes that the axial force $H_{32} = pR_1/2$ does not act at the mean radius of the body. In view of this eccentricity, one may proceed as for Free Body 1 and replace the eccentric force by $H'_{32} = H_{32}$ acting at the mean radius and a bending moment arising from the eccentricity. This bending moment, in view of EQUATION 25*b*, is given by

$$m_{32} = pR_1t_1\,(\lambda - r)/4 \quad (36)$$

where $\lambda = t_3/t_1$. Similarly, if the force F, due to the pressure acting on the closure, is assumed distributed around the inner edge of Free Body 3, it induces a bending moment on Free Body 3, whose magnitude is $n_{32} = F\lambda t_1/2$. These effects may be combined with the original moment M_{32} to yield a net moment $M'_{32} = M_{32} - m_{32} - n_{32}$, which may now be rewritten

$$M'_{32} = M_{32} - pR_1t_1\,(2\lambda - r)/4 \quad (37)$$

Since H_{32} and F are of equal magnitude but act in opposite directions, the net axial load on Free Body 3 is zero. Furthermore, the body is not acted upon by internal pressure or loading at the right end. Consequently, in EQUATIONS 16, 17, 18, and 19, $T = H = p = M_R = Q_R = 0$, and the deformation expression for Free Body 3 may be rewritten

$$\theta_{32} = -(bS_3\rho^{1/2}/E\lambda^{5/2}t_1^2)\,M'_{32} + (cB_3\rho/E\lambda^2 t_1)\,Q_{32}$$
$$w_{32} = -(cB_3\rho/E\lambda^2 t_1)\,M'_{32} + (dL_3\rho^{3/2}/E\lambda^{3/2})\,Q_{32}$$
$$\theta_{3R} = -(bY_3\rho^{1/2}/E\lambda^{5/2}t_1^2)\,M'_{32} + (cK_3\rho/E\lambda^2 t_1)\,Q_{32} \qquad (38)$$
$$w_{3R} = (cK_3\rho/E\lambda^2 t_1)\,M'_{32} - (dV_3\rho^{3/2}/E\lambda^{3/2})\,Q_{32}$$

where ρ is again equal to R_1/t_1. The subscript 3 on the influence coefficients K, B, S, Y, L, and V indicate that they refer to Free Body 3.

Upon substituting the expressions for M'_{32} given by EQUATION 37 into EQUATIONS 38 and multiplying the resulting deflection and rotation equations by α and γ, respectively, one obtains

$$\gamma\theta_{32} = -(bS_3/\lambda^{5/2})\,Z_3 + (cB_3/\lambda^2)\,Z_4 + bS_3\,(2\lambda - r)/4\lambda^{5/2}$$
$$\alpha w_{32} = -(cB_3/\lambda^2)\,Z_3 + (dL_3/\lambda^{3/2})\,Z_4 + cB_3\,(2\lambda - r)/4\lambda^2$$
$$\gamma\theta_{3R} = -(bY_3/\lambda^{5/2})\,Z_3 + (cK_3/\lambda^2)\,Z_4 + bY_3\,(2\lambda - r)/4\lambda^{5/2} \qquad (39)$$
$$\alpha w_{3R} = (cK_3/\lambda^2)\,Z_3 - (dV_3/\lambda^{3/2})\,Z_4 - cK_3\,(2\lambda - r)/4\lambda^2$$

where the dimensionless ratios Z_3 and Z_4 are those defined in EQUATIONS 32.

EQUATIONS 33, 35, and 39 describe the deformations of the three free bodies at their surfaces of separation. For continuity of deformation at a junction of free bodies, the displacement and rotation at the left of the junction must equal the displacement and rotation at the right of the junction. Thus, one may write the continuity expressions

$$\gamma\theta_{12} = \gamma\theta_{21};\quad \alpha w_{12} = \alpha w_{21};\quad \gamma\theta_{23} = \gamma\theta_{32};\quad \alpha w_{23} = \alpha w_{32} \qquad (40)$$

When EQUATIONS 33, 35, and 39 are substituted into EQUATIONS 40, four simultaneous equations are obtained

$$\begin{aligned}
&\text{I}\,Z_1 + \text{II}\,Z_2 + \text{III}\,Z_3 + \text{IV}\,Z_4 + \text{V} = 0\\
&\text{II}\,Z_1 + \text{VI}\,Z_2 + \text{VII}\,Z_3 + \text{VIII}\,Z_4 + \text{IX} = 0\\
&\text{III}\,Z_1 + \text{VII}\,Z_2 + \text{X}\,Z_3 + \text{XI}\,Z_4 + \text{XII} = 0\\
&\text{IV}\,Z_1 + \text{VIII}\,Z_2 + \text{XI}\,Z_3 + \text{XIII}\,Z_4 + \text{XIV} = 0
\end{aligned} \qquad (41)$$

from which the unknown resultant shear forces and bending moments may be found. The unknown quantities are proportional to the terms, Z_1, Z_2,

Z_3, and Z_4 according to EQUATIONS 32. The coefficients I through XIV, which appear in EQUATIONS 41, are defined as

$$\begin{aligned}
&\text{I} = -b[2 + (S_2/\tau^{5/2})] && \text{VIII} = -dV_2/\tau^{3/2} \\
&\text{II} = -c[1 - (B_2/\tau^2)] && \text{IX} = (c/4)(1-\tau) - (1-\mu/2)[1 - (1/\tau)] \\
&\text{III} = bY_2/\tau^{5/2} && \text{X} = -b[(S_2/\tau^{5/2}) + (S_3/\lambda^{5/2})] \\
&\text{IV} = cK_2/\tau^2 && \text{XI} = -c[(B_2/\tau^2) - (B_3/\lambda^2)] \qquad (42) \\
&\text{V} = a(1-\tau)/4 && \text{XII} = bS_3(2\lambda - \tau)/4\lambda^{5/2} \\
&\text{VI} = -d[1 + (L_2/\tau^{3/2})] && \text{XIII} = -d[(L_2/\tau^{3/2}) + (L_3/\lambda^{3/2})] \\
&\text{VII} = -cK_2/\tau^2 && \text{XIV} = -[cB_3(2\lambda - \tau)/4\lambda^2] - [f/\tau]
\end{aligned}$$

For a given design, the constants a, b, c, and d are functions of only Poisson's ratio and have numerical values as shown in TABLE 2. The influence coefficients K, B, S, Y, L, and V for free bodies 2 and 3 are functions of $\beta\ell$ for the bodies and may be found in TABLE 1 if the value of $\beta\ell$ lies within the range $0.5 \leq \beta\ell \leq 5.0$, or from EQUATIONS 21 if $\beta\ell < 0.5$. Thus, EQUATIONS 41 represent four simultaneous expressions from which the dimensionless ratios Z_1, Z_2, Z_3, and Z_4 may be evaluated. The numerical value of the deflection and rotation at a junction may be determined by introducing these ratios into either of the two equations that describe the deformations at this junction. The coefficients α and γ appearing in front of w and θ are given by EQUATIONS 31.

The resultant bending moments and shear forces, which may also be of interest in a subsequent stress calculation, can be found from EQUATIONS 32.

It may be observed that with the use of the sign convention established earlier, the coefficients of the Z terms in EQUATIONS 41 form a matrix that is symmetrical with respect to the principal diagonal. This property may serve as an interim check in numerical computations.

Furthermore, it is now evident that the entire analysis of the problem is expressed in terms of only the dimensionless influence coefficients and the wall thickness ratios, thus permitting relatively simple and expedient solutions of a large class of problems.

The Semi-Infinite Rocket Recessed To Accomodate a Square Key

The analysis of the previous section may be applied to rocket structures similar to the one shown in FIGURE 1 in order to evaluate the effect of

the portion of the wall that extends beyond the keyway on the stiffness of the structure. Specifically, this section of the paper is concerned with a special case of the problem that is often encountered in practice, namely, the case where the wall thickness is uniform and recessed to accommodate a key of square cross section. Thus for the special case

$$t_2 = t_1/2; \quad t_3 = t_1; \quad \ell_2 = t_1 \tag{43}$$

and

$$r = t_2/t_1 = 1/2; \quad \lambda = t_3/t_1 = 1 \tag{44}$$

To obtain an over-all view of the stiffening effect in this special case, numerical values are determined for the deformations at Section *B-B* in FIGURE 1 for various values of $(\beta\ell)_2$ and $(\beta\ell)_3$. These deformations may be used as a measure of the stiffness of the structure. The numerical value of $(\beta\ell)_2$, of course, is determined by the design of the keyway, and the numerical value of $(\beta\ell)_3$ is determined by the design of the reinforcing section, Free Body 3.

For the particular case in which Poisson's ratio μ is 0.3, $(\beta\ell)_2 = 0.5$ and $(\beta\ell)_3 = 0.2$, calcualtions reveal that $\gamma\theta_{32} = 6.315$ and $\alpha w_{32} = -2.305$. The results of other similar calculations for three different values of $(\beta\ell)_2$ and a range of $(\beta\ell)_3$ are depicted in FIGURE 5, which shows the dimensionless radial displacement αw_{32} plotted against $(\beta\ell)_3$. It can be seen that for a constant value of $(\beta\ell)_2$ the radial deflection decreases with an increase in length of Free Body 3. The rate of decrease is quite pronounced for $(\beta\ell)_3 < 1.0$, but diminishes rapidly until the effect of additional material becomes negligible for large values of $(\beta\ell)_3$. It may also be observed that the curves corresponding to $(\beta\ell)_2 = 0.2$, and 0.3 are indistinguishable from each other for the scale used. One would similarly expect to find that the curves for $(\beta\ell)_2 < 0.2$ do not differ markedly from those for $(\beta\ell)_2 = 0.3$.

Examination of the curves of FIGURE 5 further reveals that there does exist an optimum design, at which the addition of more material does not produce a noticeable increase in the rigidity of the structure (addition of material does, of course, add to the over-all weight). In general, this optimum design occurs for $1.0 < (\beta\ell)_3 < 2.0$. Since the maximum rigidity of the structure is essentially attained at $(\beta\ell)_3 = 1.0$, this single condition may be selected, for the sake of simplicity, as representative of the optimum condition.

A similar set of computations for the dimensionless rotation $\gamma\theta_{32}$ leads to an identical conclusion.

For steel, for which Poisson's ratio is 0.3, the optimum length corresponding to $(\beta\ell)_3 = 1.0$ may be expressed, in view of EQUATIONS 2 and 44, as

$$\ell_{3\ \text{optimum}} = 0.778\sqrt{R_1 t_1} \tag{45}$$

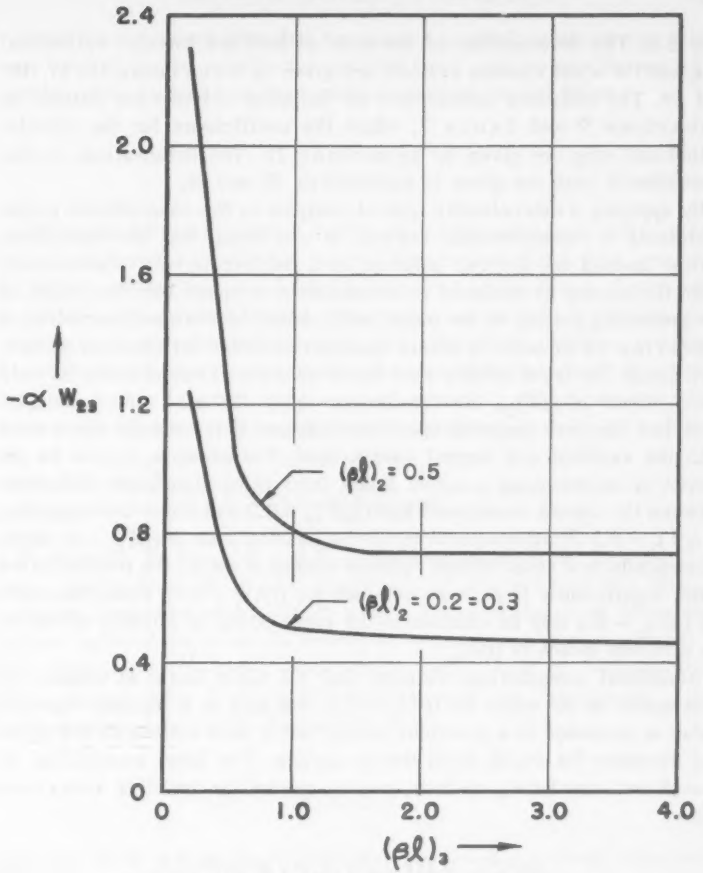

FIGURE 5. The radial displacement at section *BB*.

This simple relationship may be employed in design to obtain a structure of maximum rigidity at minimum weight.

Concluding Remarks

Analyses of the circular cylinder subjected to axially symmetrical loads have shown that it is possible to categorize the problem into three basic types: the circular cylindrical ring, the short circular cylinder, and the semi-infinite circular cylinder. In summary, a unit may be considered a circular cylindrical ring when its value of $\beta\ell < 0.5$, a short circular cylinder when $0.5 \leq \beta\ell \leq 5.0$, and a semi-infinite circular cylinder when

$\beta > 5.0$. The deformations of the ends of both the circular cylindrical ring and the short circular cylinder are given by EQUATIONS 16, 17, 18, and 19. The influence coefficients for the short cylinder are defined in EQUATIONS 9 and TABLE 1, while the coefficients for the circular cylindrical ring are given by EQUATIONS 21. The deformations in the semi-infinite case are given in EQUATIONS 23 and 24.

By applying a discontinuity type of analysis to the semi-infinite rocket containing a circumferential keyway, it was found that the cylindrical portion beyond the keyway behaves as a reinforcing ring. Furthermore, when the keyway is designed to accommodate a square key, the length of the protruding portion of the rocket wall should be designed according to EQUATION 45 in order to obtain maximum stiffness for minimum weight.

Although the latter results were based on a set of calculations for only three values of $(\beta\ell)_2$, the conclusions apply for most rocket designs. This fact becomes apparent upon investigation of the results associated with the smallest and largest values used. For example, it may be observed by re-examining FIGURE 5 that there is no significant difference between the curves corresponding to $(\beta\ell)_2 = 0.2$ and those corresponding to $(\beta\ell)_2 = 0.3$. Furthermore, even for the limiting case of $(\beta\ell)_2 = 0$, which corresponds to a semi-infinite cylinder without a notch, the results do not differ significantly from those obtained for $(\beta\ell)_2 = 0.3$. Thus, the curve for $(\beta\ell)_2 = 0.3$ may be considered the lower bound of a family of curves for different values of $(\beta\ell)_2$.

Additional computations indicate that the upper bound is closely approximated by the curve for $(\beta\ell)_2 = 0.5$. Not only is it unlikely that this value is exceeded in a practical design, but it also represents the thickest structure for which shell theory applies. The latter conclusion, although not immediately obvious, may be reached by rewriting EQUATION 2 as

$$(\beta^4\ell^4)_2 = 3(1-\mu^2)(\ell_2)^4 / R_1^2 r^2 t_1^2 \tag{46}$$

and then letting $\ell_2 = t_1$ and $r = 1/2$, so that

$$(\beta\ell)_2 = 1.818/\sqrt{\rho} \tag{47}$$

where $\rho = R_1/t_1$. The numerical value of $(\beta\ell)_2 = 0.5$ corresponds to $\rho = 13.21$. Since shell theory applies only for $\rho > 10$, and it has been the foundation for the entire study, obviously this study would have little meaning for $\rho < 10$.

In developing the simple criteria established in this paper, attention was given only to the deformation problem and not to the associated stress problem. It is suggested that the latter effect be considered as a separate problem after establishing a given design with the optimum length as prescribed in EQUATION 45.

It may be remarked also that the manner in which discontinuity theory was applied to the axially symmetrical shell problem may be useful in solving other problems in the rocket or pressure vessel fields.

Summary

The relationships between a system of axially symmetric loads applied to a thin circular cylinder and the resulting deformations were presented in a form particularly adaptable to numerical calculations. These relationships were applied to the problem of a semi-infinite rocket wall, containing a circumferential keyway and subjected to internal pressure. A simple design formula was derived that specifies the length of cylinder from the keyway to the end of the rocket needed to obtain maximum stiffness in the structure while making most economical use of the material.

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DIVISION OF PSYCHOLOGY

BIODYNAMICS OF EVERYDAY LIFE*

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By applying the natural laws, as previously formulated (Kempf, 1958b), of holistic electrodynamic organization of the pyramiding equilibrating interactions of bound parts in reaction to environmental actions, we can account for the dynamic economies in the differentiation and development of specialized organs in special functional parts of the plant or animal organism. We can account also for the holistic organization in animals of pyramiding levels of cellular equilibrating interactions into an environmentally self-righting, self-determining, and adaptive personal attitude with sensory discriminative consciousness of itself and its environment.

We can likewise account for the mechanical and chemical differences in the evolution of species under the selective action of differences in limiting environmental conditions. By destruction of the unfit, limiting environmental energic conditions direct the course of evolution concomitantly of the whole reproductive cycle (such as bisexually differentiated parents, ova, sperm, zygote, embryo) toward the growth of organs that are more economically adapted for work in such environmental conditions. Thereby the genotype of each part evolves consistently within the potential pangenic variability of the species. Increases in dimensions of homologous, more used organs with equilibrating reductions of less used organs consistently with parallel changes in the nervous system determine the similarities and differences in the behavior of species and their selections of habitats.

Because of environmental limitations of time and space I shall confine my discussion to a diagrammatic sketch of the major biodynamics of holistic organization of the equilibrating interactions of the circular reflexes, composed of sensory and motor neuron connections with muscular and glandular systems of organs of the human organism. This will indicate sufficiently for psychology and sociology how the cells, as the units of life of the organism, integrate their functions in a pyramiding series of levels to produce its environmentally self-determining and adaptive mind. I can then show how the same laws of holistic organization of the equilibrating interactions of bound units determine the self-determining and adaptive adjustments of social attitudes when two, three, four, five, and more persons are bound to function interdependently.

Every living thing is a highly specialized, genetically determined, electrochemically self-constructing, and self-consuming biodynamic

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mechanism that is adapted to work, rest, and reproduce in a narrow range of environmental quantitative variations of heat, light, moisture, salinity, and nutritional supplies that it must work endlessly to acquire as needed for equilibration. All environmental conditions outside this range are potentially stressing and destructive to the organism and more so to its reproductive cycle, and must therefore be avoided.

Each person, like every other organism, must work to find and capture sufficient quantities of specific kinds of food, shelter, and living space as needed to carry on the self-conserving metabolism of recuperation from fatigue and wear and tear of injury and disease in order to survive, mate, and complete the cycle of growth and reproduction. All internal and external stimuli of sensations are differentiated for acquisitive or avoidance conditioning effects by the consciously self-determining attitude as it is maintaining itself in patterns of cerebral integration at the time of stimulation. Beneficial environmental conditions for every need are specialized and surrounded in every direction by unfit if not dangerous conditions. They are often so much alike and so close together in space and or time that discrimination of their values is difficult, if not impossible.

Hence the organism must organize the functioning of its parts so as to maintain a consciously self-determining and adaptive attitude that is ready to discriminate acquisitively whatever it needs and concomitantly avoid doing whatever is useless, frustrating, or dangerous. Internal and/or external conditions that excite its acquisitive functioning must reciprocally inhibit its avoidance functioning. Conversely, conditions that excite avoidance must inhibit acquisitive functioning. Thereby only can the self-determining attitude maintain its integrity and control its reactions to its environment.

Obviously, conservation of energy through economy in spacing and timing holistic organization and its uses of energy is as indispensable as capturing energy. Man has developed organic mechanisms and accessory, mechanical devices and social attitudes and social organizations in order to extend as far as possible in space and time control of his external environment and internal needs with maximal returns for minimal uses of energy.

When a person, like any other animal, gets into an unadaptable attitude in an unavoidable situation and is forced under increasing danger of punishment to make a serious decision to act acquisitively or avoidantly toward the situation, that is, to do or not do a certain thing, both his somatic and autonomic systems become excited into unreciprocally conflicting interactions that increase as the limitations of space and/or time decrease. This produces the distressing somatic and visceral tensions and tremors known as anxiety. Loss of skill and power follows, attended by mental confusion and increasing indecision with general

incompetence. Obviously this split-minded state is dangerous for survival in the struggle for life. It is the state that dominant persons try to impose upon their opponents in order to subjugate them. When this state is continued indefinitely it constitutes the basis of neurosis and psychosis or revolutionary and criminal compulsions against established law and order.

In order to understand the equilibrating biodynamic adjustments between two or more human or lesser animals when they are bound by limiting environmental conditions to live interdependently with each other, we need to know how their organs reflexly produce economizing, emotivating, and mental drives toward making socially equilibrating adjustments.

The neuromuscular systems of vertebrates are mechanically and dynamically differentiated into autonomic and somatic divisions. The autonomic visceral system is composed of functionally specialized tubes of slowly contracting muscular organs lined with secretory glands. Normally the organs contract and secrete so as to move distending contents at equilibrating pressures and rates. The alimentary system serves the digestion of energy-giving food and the elimination of its waste products; the vascular system serves the assimilation, storing, releasing, and circulation of nutritional energic substances; the respiratory system serves the elimination of the metabolic excesses of carbon dioxide and moisture and the counterbalancing assimilation of oxygen; the renal system serves the elimination of metabolic waste solutions; and the sexual organs serve reproduction.

The autonomic system has a dual, reciprocally opposed, more or less active motor innervation. The segmentally distributed parasympathetic division serves the intake and conservation and use of energy for growth and reproduction and recovery from fatigue and injury. The sympathetic, generally distributed division serves the release, circulation, and expenditure of energy for work. The viscera also have a single system of sensory innervations in each organ that is reactive to its contractural tensions against distending contents.

Any kind of internal and/or external increase of stress or reduction of equilibration inhibitorially reduces parasympathetic action and excites increase of sympathetic action. Thereby is increased the release of energic substances into the blood and the rate and amplitude of cardiac contractions and arterial constrictions and the pressure and rate of distribution in capillaries to support the work of the stressed organs. Reciprocally, the vascular supply to the alimentary system is reduced and the digestive processes tend to be inhibited.

Any kind of reduction of internal and/or external stress toward easing the work of equilibration reduces sympathetic action and increases parasympathetic action toward reducing general vascular distribution and increasing digestive vascular distribution and the assimilation and conservation of energic substances.

The streams of sensory impulses flowing into the central nervous system from the different visceral organs produce in the conscious state of the organism special feelings that represent the special degrees of their contractural tensions against distentions, as, for example, feelings of hunger, nausea, or disgust originate in different kinds of contraction of the stomach.

The whole neurocardiovascular hemodynamic system functions as the basic, endlessly active, internally and externally equilibrating, energy-supplying, waste-removing, holistically emotivating mechanism of the organism. The differences in feeling of the compelling emotions of fear, love, hate, jealousy, joy, shame, sorrow are produced (Kemph, 1953, 1958a, 1958b) by differences in the rates and amplitudes of cardiac contraction and vascular distribution in different organs of the body and by differences in the energic constitution of the blood. Differences in the feelings of emotional pressure are further accentuated by the differences in the holistic attitude of the organism toward its environment and its abilities to get what it needs and avoid or overcome what is unfit or frustrating.

The somatic-kinesthetizing energy-projicient system is composed of mechanical arrangements of flexor and extensor muscles that contract reciprocally, as allies and antagonists, on the skeletal system of levers, against the stretch of gravity and other forces. Each muscle is composed of many bundles of many quickly contracting cellular units. Each bundle has a single motor innervation and a dual propriosensory innervation. Increase of stretch on a muscle increasingly stimulates the sensory nerves that excite its motor nurons and thereby increase the muscle's quantity of contractions. Reciprocally, decrease of stretch excites the sensory neurons that inhibit the motor neurons and thereby reduces the contractions of the muscle. Through reciprocally equilibrating contractions against gravity and all other external forces, all of the circular sensory-motor-muscular reflexes of the somatic kinesthetic system organize their functions according to their mechanical arrangements into a holistic, self-equilibrating, self-righting, self-determining, environmentally adaptive mechanism that supports the work of its autonomic organs and acquires from the environment whatever relieves their needs and cravings.

All simultaneously active circular reflexes of the autonomic and somatic systems intercondition each other through forming holistic patterns of sensory neuron connections in a series of pyramiding levels in the brain. In both the autonomic and somatic systems the capacity of the different muscles to contract against stretching forces determines the rate and thereby the timing and spacing of the quantities of inflowing emotivating and kinesthetizing nerve impulses. The muscle cells are thereby the basic conditioners of the holistic organization of the integrative actions of the nervous system.

This is dominantly true of the working powers of the heart, which is

the most repetitively contracting and burdened muscle of the body and the most readily conditionable by internal and external stimuli. The heart is the arch organizer and pacemaker of nervous integrations and vascular chemical interrelations of the whole organism.

The analytical evidence of physiology on the functions of specialized cells and organs of the organism, including the energic constitution of the blood and lymph, shows that every cellular unit and organ in the organism functions reciprocally as an ally or an antagonist with every other cell and organ toward regulating the equilibrating interactions of the whole dynamic mechanism.

Environmental self-righting, self-determining, and adaptive organization of all circular sensory-motor reflexes is genetically predetermined to develop before birth in preparation for meeting specific environmental conditions that will be experienced after birth as it develops in the reproductive direction. It is the purposive way of life, learned from past experience, to prepare for future repetitious of experience in order to continue its existence.

The processes of holistic electrodynamic organization of the equilibrating interactions of electric units of the atoms are extended into molecular organizations of atoms and cellular protoplasmic organizations of molecules and organismic organizations of cells.

In man the spinal and medullary level of nervous integration is the means of equilibrating circulation, respiration, and digestion. The hypothalamic level equilibrates heat production and radiation with endocrine secretion. By means of the diencephalic integrations the autonomic and somatic systems organize their interactions into holistic subconscious, self-righting antigravity postures and movements in reaction to external contact stimuli. By means of the cerebral cortical integrations this self-righting organization forms the consciously self-determining acquisitive and avoidance discriminating person that projects itself in space and time through the visual, auditory, and olfactory senses. By living in a more or less intelligently speaking social group it learns to speak and use vocal, manual, and other symbolical sensory representations for communication with other persons.

It has often been said that "the brain is the organ of mind." Actually the holistic pyramiding electrodynamic organization of the economically equilibrating interactions of the different organs, as fixed in mechanically related positions in the organism and reacting in repetitive patterns to repetitively conditioning internal and environmental stimuli is the organ of mind. Without such repetitive holistic organizations of equilibration patterns of autogenous somatic and autonomic sensations, in coordination with environmental adaptations and sensory stimulation, mind is not produced by the brain.

Each person is naturally a self-preserving, biodynamic, more or less

egocentric, self-determining and adaptive organization that is driven by the economies of its vital functions to get as much as possible of firstness, bestness, and mostness, in the easiest and quickest and surest way, out of its interpersonal relations and greater social situations. Thereby it is naturally the self-loving, potentially jealous rival of every other person in its special economic, emotional, and mental interests. At the same time, it is so dependent upon many persons. Like the cell in the organism, it works to preserve the social organization as long as it is the means of preserving itself.

Each person lives in more or less closely binding family and other social groups in which each imposes upon every other person pressures of sympathetic suggestion, appeals, and approvals in order to increase cooperation, and antipathic demands and disapprovals to reduce opposition. Each person learns through successful experiences how to develop more self-determining attitudes (Kempf, 1945) in order better to focus and direct attention for making acquisitive versus avoidance decisions. Thereby he increases his positive thinking and powers of suggestion over other people and reduces his submissive suggestibility to other people. Failures tend to break down self-confidence.

The drive for survival with reproduction in bisexually differentiated mankind is the means of extending the life of the individual through extending the life of the family, tribe, and nation, Mother and child constitute the most dependently interactive units of the family and, in all races, they form the hub of organizing the protective interactions of the social circle. The mother is normally compelled by her endocrine disposition to nurse, clean, protect, and cherish the infant, and the helpless infant naturally needs and claims such attentions. As the infant grows, its development of a self-reliant, self-determining attitude depends largely upon the ways its parents, particularly the mother, evaluate what it does and how they give loving approvals and disapprovals to encourage the development of its egocentric estimation of itself and its abilities. When the child obtains admiration and approvals too easily, it develops a weak, soft, careless, flattery-loving attitude. Proportionately well-expressed and timed approvals by parents for earnest, creative work stimulate the child to have self-confidence and pride in its abilities. Too much criticism and harsh neglect tend to make the child progressively self-doubtful, unhappy, confused, rebellious, and antisocial. It becomes obsessed to claim as naturally right that each person should give according to his abilities to each according to his needs. In either case we see the child working to increase its social equilibrations and reduce stress.

When two people are bound to work together, the stronger generally dominates the weaker. When three people are bound to work together in a family or other situation, two generally become more intimately inter-

dependent and the third is placed more or less outside. As the two more sympathetic intimates exchange mutually encouraging approvals, they enjoy easier if not superior self-righting reassurances, and the frustrated outsider in the triangle tends to doubt his social desirability, if not his efficiency. The dramatic arts have portrayed the human triangle with infinite variations of its conflicts. Here we are interested particularly in the biodynamics of adjustments between the individuals of a group.

When the situation involves intensely desired economic advantages, social honors, or sexual love, the two intimates get intense pleasure out having what the unhappy outsider wants intensely. They enjoy ridiculing and criticizing his frustrations if he becomes impotently jealous and resentful. If he is potently jealous he becomes dangerously obsessed to pay back and get even in order to restore his self-respect. When such adjustments between three people develop in an unavoidable family or business situation the conflict may grow desperate: as when one parent becomes jealous of the other parent and child, or a husband opposes his wife and mother-in-law, or two men court the same girl who jilts one for the other.

If the jealous outsider represses his emotions to conceal his frustration he loses integrity and becomes less able to discriminate right from wrong, and to decide what to do or not to do. His mind tends to become forced into a state of unreciprocal acquisitive and avoidance conflict with miserable visceral tensions. As the situation grows worse the two sympathetic persons become more obsessed with self-righting justifications and compulsions to make the frustrated person admit wrong, even to the degree of breaking down his integrity, self-reliance, and judgment. He then becomes obsessed with wishes for the death of the persons who dominate him. If his repressed jealousy is introverted, it works insidiously toward destroying himself as the means of punishing those who are bound to him. Herein is the compelling emotion of alcoholism, suicide, and psychosis.

A fourth person, such as confidential friend, physician, minister, or lawyer, is often called into the situation. When the fourth person understands the conflicting emotivations and sympathizes with the difficulties of the outsider and justifies his complaints, his attitude changes toward decreasing self-doubt and self-repression and increasing self-confidence in his social desirability. His powers of self-expression and consistency and integrity of mind increase and body tensions decrease. When peace and satisfaction cannot be obtained in conflicts among four persons, a fifth is often called in to judge the claims and rights of both sides. The wisdom of his duly considered judgment is generally designed to bring peace with moral justification to both sides.

Social organization is generally based on the economically, emotionally, and mentally equilibrating interactions among five or more persons

bound to live together for mutual protection. The eternal problem is the reconciliation of egocentric jealousy. The primitive systems of social organization under jealous struggles between individuals for power, with justifying rationalizations, authoritative positions, and uses of force, are essentially gangster systems. The stronger, better organized group follows a tyrannical leader in order to dominate and exploit the unorganized masses. Here, graded powers make graded rights.

In the past three thousand years, with the increase of literacy and intelligence and more closely binding time- and space-reducing mechanisms, more democratic forms of social organization have been evolving through the culture of renunciation of jealousy with increase of sympathetic cooperation and mutual assurance of equal legal rights. The equilibrating moral code of democracy is for each to treat others as he wishes to be treated. Such fraternalism upholds the self-determination and self-respect of each person above property values. The alleged communistic code of each giving according to his ability to each according to his needs is the philosophy of frustrated infantilism. It softens incentive and discourages the development of self-reliance and self-respect and increases cynical apathy. The culture of altruistic self-determination in which each person, like the cell in the organism, both gives and receives according to his needs and abilities is the indispensable necessity of healthy minds in healthy democratic social organizations.

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DIVISION OF INSTRUMENTATION

EVALUATION OF OPTICAL METHODS IN BIOMEDICAL RESEARCH*

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Abstract

The elegance and efficacy of optical methods rest upon their utilization of beams of photons as the finest available means of probing the objects under study. It is convenient to view optical observations and measurements as interactions among object, instruments, and subject, resulting in the transfer of a finite amount of information. Thus, the optical evaluation of instruments and methods becomes a search for the best way of effecting this transfer.

A survey of several basic theorems of geometric optics includes Fresnel's construction, Babinet's theorem of complementary diaphragms, de Fermat's principle, and the Malus theorem. The present study points to the need to supplement the deficiencies of the geometric approach. One of the relatively simple ways of achieving this objective utilizes a method of spatial frequency analysis. Thus, every optical system transfer function can be characterized by a finite frequency-response characteristic. It is shown that simple relations exist between the Shuster slip factor, the Rayleigh resolution, effective slit width, *f*number and numerical aperture, and the cut-off frequency at the resolution limit of linear noisy optical communication channels considered as low band-pass frequency filters. These considerations lead to the formulation of performance criteria of a statistical nature that are quite readily accessible to experimentation (relative image structural content, fidelity factor, Strehl definition, correlation factor, and O'Neill sharpness factory). The practical use of these new concepts is facilitated by the introduction of the sampling theorem, which permits the prediction of the best filtering to be used in each case (such as periodic objects, transients, and random objects) The analogies between optical and electronic channels lead to an interpretation of optical noise as the sum of all the aberrations plus transient disturbances.

Contemporary methods of image-frequency filtration and evaluation (such as apodization, coating functions, two-wave-length reimaging, and amplitude contrast process) are briefly reviewed from the parallel standpoints of a general interaction theory, the Shannon theorem of communication, and Ingelstam's theorem of optical indeterminacy. The latter theorem probably opens the best way for a more complete interpretation of the optical observation of biological objects.

*This paper, illustrated with slides, was presented at a meeting of the Division on January 20, 1959. It will be published in the *Annals of The New York Academy of Sciences.*

DIVISION OF MYCOLOGY

THE HALLUCINOGENIC MUSHROOMS OF MEXICO: AN ADVENTURE IN ETHNOMYCOLOGICAL EXPLORATION*

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Our inquiries into the hallucinogenic mushrooms, after six years and more of research, are now at the end of their first phase.

In Paris, a book on our mushrooms has just been published by the *Muséum National d'Histoire Naturelle*. Handsomely illustrated, it deals with every aspect of this strange mushroom complex—anthropological, linguistic, historical, archeological, mycological, chemical, psychological, and religious — and even the initial steps in the therapeutic use of the active agent in the mushrooms. Roger Heim, director of the muséum, is the author, and he has done me the signal honor of joining my name to his on the title page. On January 29, 1959, an exhibition illustrating our mushrooms and our experiences with them opened in the American Museum of Natural History, New York, N.Y., to which the Paris Muséum has generously lent its collaboration. Thus publication of this paper offers a timely and welcome opportunity to report on our remarkable adventure in ethnomycology.†

It was in September 1952 that my late wife and I first learned of the existence of a mushroom cult among the Indian tribes of southern Mexico. Immediately we undertook, in our spare time, to learn all that had been published about it. There were only three modern papers on this cult that contributed helpful information. However, in the old writings about Mexico, dating mostly from the Sixteenth and Seventeenth Centuries, we found a number of references to it, all of them of absorbing interest to us. We undertook to make an anthology of these quotations, upwards of a score of them, some of them existing only in manuscripts of the time. We were helped in this search for the sources by kind friends, notably by those eminent authorities on ancient Mexico, Robert J. Weitlaner and his daughter, Irmgard Weitlaner-Johnson. We analyzed these quotations, pinpointing on the map of Mexico the places to which they referred, collating the descriptions of the fungi, and scrutinizing what was said about the use of the mushrooms. We undertook to peruse the archeological record in Meso-America; and what an extraordinarily com-

*This paper, illustrated with slides, was presented at a meeting of the Division on January 23, 1959.

†"Ethnomycology" was a word coined by us, after the analogy of ethnobotany, to signify the role played by mushrooms in the history of human cultures. It first appeared in print in 1954 in an invitation sent out by the American Geographical Society, New York, N.Y., to a lecture that we were to give before that body.

plex, rich, and enigmatic record it is! We believe that we have discovered, for the first time, our sacred mushrooms in that record. In our forthcoming book we publish the text of all our quotations, and we submit the archeological evidence for the mushroom cult to the judgment of those qualified in this thorny field of recondite learning.

Here a number of questions will occur to the mycologist. What mushroom or mushrooms are worshipped? Many of the old writers speak of the visions that these fungi cause. Do they really produce visions? If so, what is the active agent in them that provokes such a response? What is its molecular structure? Could it be used in therapeutics?

Then there is the anthropological problem. What were the geographical limits of the cult in the old days and where does it survive now, if at all? What role does the mushroom play in the lives of the Indians? The cult lingers in the areas where it existed earlier, in the uplands of southern Mexico, roughly from the latitude of Mexico City to the Isthmus of Tehuantepec. It survives feebly if at all in the cities and surrounding country, but in full vigor off the highways, in Indian villages where the native languages are still in current use. In these remote places the sacred mushroom holds the entire population in its grip. The anthropologists have overlooked it simply because they have not asked about it and the Indians do not volunteer to talk about it.

Not all anthropologists are temperamentally suited for studying such a phenomenon as the mushroom rite among the primitive Indians of Mexico. The anthropological discipline schools its neophytes in a respect for hard, down-to-earth facts. These students are prepared to arrive at the systems of kinship and marriage among the peoples they study, the rules of land tenure and exploitation, the methods of manufacture of textiles and other artifacts, the customs governing the exchange of goods, the calendar systems, and the native cosmologic and eschatological ideas. By the nature of the archeological discipline, there is a natural selection of persons who are not poets, not mystics, not skilled in assessing subjective emotions. Yet in primitive man the poetic element, the religious feeling, exists, and it richly deserves the attention of the modern world. The difference I speak of is the difference between the beauty of a bird in flight and the taxonomist's description of that same bird's flight muscles; between the breathless beauty of a rainbow and the physicist's spectrum analysis of that same rainbow. The divine mushroom that causes the eater to see visions plays perforce a vital role in the inner life of the Indian, that aspect of his life which he is reluctant to discuss with strangers of another race and language, and doubly so if those strangers would not enter into the experience sympathetically. The anthropologist who explores these subjects should possess the soul of a poet and the tact of a father confessor, yet he must not let his own imagination run away with him. He must observe, with the eye of a poet, the role of the mushroom in a

primitive culture far removed from his own, and confine himself to that function. His task resembles the problem of a translator of poetry, who must possess poetic feeling and yet harness his own Pegasus to another man's imagination. How seldom do we meet with a good translation of poetry! So it is, I feel, with the anthropologist's study of the subjective religious life of the Mexican Indian. Trained from the beginning to an austere respect for nuggets of fact, most anthropologists – not all – are ill-prepared to enter into the poetic world of the subjective life of the people they are studying, for exploring the world revealed by the sacred mushroom. We at least are alive to the problem. In our writings about the mushroom cult we have tried to escape the Scylla of dry factualism and also the Charybdis of unbridled imagination.

Each year since 1953 we have made expeditions to southern Mexico, to the remote mountain fastnesses where the mushroom cult survives, traveling intentionally in the rainy season, by mule over mountain trails, often in the rain, to live in the Indian villages where the Spanish language is known only to a few head men. Our first and essential task was to win the confidence of the Indians. Their initial reaction to our presence was always reserved, occasionally hostile: the Indians have had contact with white men for centuries, and we are not viewed with the favor one should like. Our attitude was that of humble suppliants coming to learn the secrets of the sacred mushroom for the benefit of our own people. After an interval the Indians met us more than halfway.

From the beginning we had three objectives: (1) to obtain some of the sacred mushrooms; (2) to attend the ceremony in which they are eaten; and (3) to share in the eating. We were intent on learning everything about the cult: how and when the mushrooms are gathered; how they change hands and reach the ultimate consumer, the Indian (and Spanish, if any) names for the mushrooms; the meaning of those names; the manner of performing the ceremony in the different tribes and villages; the purpose of the ceremony; whether the mushrooms are really psychotropic; what one experiences on eating them; and the dosage. We were eager to get photographs and tape recordings of the ceremony, to study the words linguistically and religiously, to identify the mushrooms, to isolate the active agent (if any), to describe this agent's molecular structure, to define its properties, and, finally, to place our mushroom cult in the context of what is known of primitive religious behavior. A little more than six years have passed since we began to devote our spare time to this avocation, and we have now attained all these objectives in some degree.

The identification of our mushrooms proved much more complicated and exciting than we had imagined. The old writers had given inadequate descriptions of these fungi, but what they said indicated that there were several species. (After all, who can blame those authors for their inadequacies, since the science of mycology had not yet been born?)

Although we expected to find several species, our discoveries went far beyond this. Each region that we visited makes use of species peculiar to itself, only a few species turning up in more than one region. The sacred mushrooms of Mexico belong, for the most part, to the genus *Psilocybe* and, except for one or two species, they are new to science. Genuinely psychotropic and hallucinogenic, they are the following, arranged according to the regions in which they were found:

Sierra Mazateca: (1) *Ps. mexicana* Heim; (2) *Ps. semperviva* Heim and Cailleux; (3) *Ps. caerulescens* Murrill var. *Mazatecorum* Heim; (4) *Ps yungensis* Singer & Smith;* (5) *Ps. acutissima Heim; (6)Stropharia cubensis* Earle (synonym: *Ps. cubensis* (Earle) Singer); and (7) *Conocybe siligineoides Heim.*†

Slopes of Popocatepetl, Valley of Mexico: (8) *Ps. Aztecorum* Heim.

Tenango del Valle: (9) *Ps. Wassonii* Heim (synonym: *Ps. muliercula* Singer & Smith).

San Agustín Loxicha, in the Sierra Costera; (10) *Ps. Zapotecorum* Heim (also No. 1, and two other species of unknown identity).

Mixería, region of San Juan Mazatlán: (11) *Ps. Hoogshageni* Heim; (12) *Ps. cordispora* Heim; and (13) *Ps. mixaeensis* Heim (also No. 1).

Yaitépec, in the Chatino country, Sierra Costera: (14) *Ps. caerulescens* Murrill var. *nigripes* Heim (also Nos. 1 and 10).

Sochiapam in the Chinantla, No. 1?

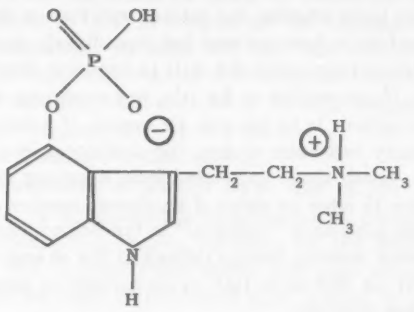
On the periphery of the area where mushrooms are used for divination, two species serve for that purpose that we believe not to be psychotropic. Their phallic suggestiveness obviously explains their role. In Tenango del Valle the Indians consume *Cordyceps capitata* in association with hallucinogenic *Psilocybe* sp. In one corner of the Chinantla the *curandera* crushes and eats *Dictyophora phalloidea* to heighten her divinatory powers.

Roger Heim of Paris, our mentor in all matters mycological, has devoted himself to the classification and study of our mushrooms and, in 1956, he joined us in the field. He identified them as Basidiomycetes and, with the aid of his young assistant Roger Cailleux, he succeeded in cultivating almost all of the fourteen species of Mexican hallucinogenic agarics in the *Laboratoire de Cryptogamie* in Paris, at first in sterile, artificial media, later in compost in hothouses, thus freeing us of our dependence on Mexico for our supply of raw material. In the Sandoz laboratories of Basel, Switzerland, with material supplied from Paris, a research team headed by Albert Hofmann and including Heim, A. Brack,

*This species poses a problem. Ingested by Thomas Davis and RGW in the field, it proved to be psychotropic and (in RGW's case) hallucinogenic. Subsequently in the laboratory the tests for psilocybin were negative.

†The psychotropic activity of this species was recognized by the Indians but, owing to paucity of material, has not been proved in the laboratory or by experiment on ourselves.

and H. Kobel succeeded in large-scale culture of *Ps. mexicana*, in sterile conditions on artificial media, isolating two distinctive substances. They called one of them psilocybin and the other psilocin, and they reduced psilocybin to a pure white crystalline powder, arrived at its molecular structure, and synthesized this compound in full (o-phosphoryl-4-hydroxy-*N*-dimethyl-tryptamine). The active agent is not an



Physical and chemical data: empirical formula, $C_{12}H_{17}O_4N_2P \cdot CH_3OH$; molecular weight, 284.3 · 32; melting point, 200 to 210° C. with decomposition; solubility, in 120 parts of water at 20° C.; and *p*H, 5.3. Keller color reaction: 0.1 mg. of psilocybin dissolved in 1 cc. 0.01 per cent ferric chloride containing acetic acid and stratified with 1 cc. concentrated sulfuric acid. After mixing, a violet color is obtained.

alkaloid nor a polypeptide but an indole structure. It contains an atom of phosphorus and, as such, is a substance new to chemical science. Psilocin, which is present in much smaller amounts, is a dephosphorization of psiocybin.

For our part, my wife and I concentrated our attention on the anthropological side of the mushroom cult. In the remote Indian villages the Indians regard the psychotropic mushrooms as holy. They fear and adore them. Although the mushrooms are nowhere any longer called by the Aztec term *teo-nanácatl*, "God's flesh," the Indians regard them as the key to communication with the Deity. The mushrooms today are eaten behind closed doors, in the silence and darkness of the night. They do not change hands in the market place for money, but are delivered privately, carefully wrapped up, perhaps in a banana leaf. The Indians do not discuss the sacred mushrooms in gatherings: you learn about them talking in a whisper with a friend who trusts you, preferably at night. *Es muy delicado*, it is very perilous, the Indians say, not to be taken lightly, and only as a sacrament. There is nothing in common, absolutely nothing, between these sacred mushrooms and our use of alcohol. The vulgar jocularity with which fully civilized peoples some-

times talk of a "binge" or a "jag" is alien to the Indian with his mushrooms. The effects are wholly different. With the mushrooms there is no hang-over, no obfuscation of the memory, and it seems that one does not become addicted to the mushrooms as one sometimes does to alcohol and certain other drugs. The dosage remains the same throughout life. The mushrooms are taken when a grave problem needs to be resolved and, I believe, only then. Perhaps there is illness in the family and the mushroom is consulted to learn whether the patient will live or die. If the verdict is for death, the family does not wait but immediately prepares for the funeral, and the sick person loses the will to live and shortly afterward gives up the ghost. If the verdict is for life, the mushroom will tell what must be done if the patient is to recover. Or, again, if a donkey has been lost or if some money has been stolen, the mushroom is consulted and gives the answers. Among these unlettered folk, speaking languages that are not written, there is often no news of an absent member of the family, perhaps one who has gone as a "wetback" to the United States. Here the mushroom, as a postal service, brings tidings of the absent one, whether he is alive and well, or sick or in jail, or prosperous or poor, or whether he is married and has children.

The method of taking the mushrooms varies. In the Mixe country the mushrooms are consumed privately by the suppliant, with only one friend present, to attend to what might happen and be a witness. In other regions a *curandero* or healer, who takes the mushrooms and who may serve them to others present, is called in. We know of two quite different rites that the *curandero* may use. In one of them the mushrooms are superimposed on the ceremony of divination that is common to all Meso-America, a much larger area than the mushroom country. In this ceremony the *curandero* casts kernels of maize, and according to the way they fall reads the answers to the questions that are put to him. Of course, there is much more to the ceremony than that: all the accessories to the rite play their part—hen's eggs, turkey eggs, *guacamaya* (macaw) feathers, *copal* (a resin), cacao beans, tapers of pure beeswax, and *amate*, or wrappings of bark. These accessories play their role with a precision, a nicety, that are equal to the reverence and care with which a priest handles the holy utensils of the Mass. In the mushroom country the *curandero* simply adds mushrooms to this customary ceremony to strengthen the divine power within him.

In the alternative ceremony the *curandero*, having partaken of the divine mushrooms, waits for them to seize hold of him and then chants his supplications to the Almighty to come down and answer the prayers and problems of those present. In this ceremony the *curandero* is esteemed according to the skill he displays in formulating the appeals to God. Today, and I dare say throughout the past, there have been *curanderos* who were frauds, *embusteros* as they are called, but it has been our privilege to know two who were not, and one of them, María Sabina,

is a woman of presence, integrity, and intelligence. The *curanderos* are called of God. That is, one becomes a *curandero* because, having taken the mushrooms, they tell one to follow that vocation. The *curanderos* are not organized in a hierarchy: each one practices his calling on his own, like the shamans of Siberia, although they may exchange ideas on occasion with each other. As a class, they are shy, usually living apart on the outskirts of town. It would be well worthwhile, before the tradition is lost, to explore all the villages where the sacred mushroom is consulted, to seek out the most proficient *curanderos*, win their confidence, and explore the recesses of their minds. These agents are the surviving repositories of the Old Religion. I am certain that they would surprise you by the content of their minds and their virtuosity in the discharge of their office.

The sacred mushrooms of Mexico seize hold of you with irresistible power. They lead to a temporary schizophrenia, or pseudoschizophrenia, in which your body lies, heavy as lead, on the *petate*, or mat, and you take notes and compare experiences with your neighbor, while your soul flies off to the ends of the world and, indeed, to other planes of existence. The mushrooms take effect differently with different persons. For example, some seem to experience only a divine euphoria, which may translate itself into uncontrollable laughter. In my case I experienced hallucinations. What I was seeing was more clearly seen than anything I had seen before. At last I was seeing with the eye of the soul, not through the coarse lenses of my natural eyes. Moreover, what I was seeing was impregnated with weighty meaning: I was awe-struck. My visions, which never repeated themselves, were of nothing seen in this world: no motor cars, no cities with skyscrapers, no jet engines. All my visions possessed a pristine quality: when I saw choir stalls in a Renaissance cathedral, they were not black with age and incense, but as though they had just come, fresh carved, from the hand of the Master. The palaces, gardens, seascapes, and mountains that I saw had that aspect of newness, of fresh beauty, that occasionally comes to all of us in a flash. I saw few persons, and then usually at a great distance, but once I saw a human figure near at hand, a woman larger than normal, staring out over a twilight sea from her cabin on the shore. It is a curious sensation: with the speed of thought you are translated wherever you desire to be, and you are there, a disembodied eye, poised in space, seeing, not seen, invisible, incorporeal.

I have placed stress on the visual hallucinations, but all the senses are equally affected, and the human organism as a whole is lifted to a plane of intense experience. A drink of water, a puff of the cigarette, is transformed, leaving you breathless with wonder and delight. The emotions and intellect are similarly stepped up. Your whole being is aquiver with life.

Our friends of Sandoz are offering this active agent for experimentation on the inmates of our hospitals for the emotionally disturbed in Paris and in Lexington, Ky. Will no one try it out on the exceptionally gifted? There is the possibility – I say no more than the possibility – that their powers will be sharpened and they will command insights not given to them in their normal existence.

While we were seeing our visions in the blackness of a tropical night, with the rain pouring outside, the *curandera* was giving voice to her canticles, invoking the deity to come down among us. She and her daughter took turns at singing. At times she would rise and engage in a complicated clapping, slapping, whacking of different parts of her body, with different resonance depending upon the part of her body that she would strike, with a complicated timing of the whacks, the blows being nicely modulated, sometimes struck lightly, sometimes with full power; and she would rotate to the cardinal points of the compass as she performed. There we were, in a humble Indian hut, with our visions and the authoritative voice of the daughter's singing in our ears, and the percussive blows of the mother displaying a ventriloquistic virtue, now here, now there, near at hand, far away, as though we were afloat in space, stroked by breezes, listening to the voice raised in song, and surrounded by the calls of eerie creatures darting around us.

The performance of the *curandera* reaches a climax every twenty or thirty minutes. Then suddenly the singing stops and the mushroom speaks. She whips out the words of the oracle, loud, sharp, with compelling authority, the syllables cutting the night air and the darkness and the silence like a knife. Afterward everyone relaxes, cigarettes are lighted, and there is general conversation in which the *curandera* participates.

After four or five hours of this experience we would all fall into a deep slumber, from which we would awaken some two hours later, refreshed and ready for work–ready, that is, except that the clear recollection of our adventure made work seem unimportant, and the important thing to do was to compare notes with our companions and record in our diary every detail of the night's events.

I have now told you what we have accomplished, in the field and the laboratory, in the past six years. We have rediscovered the sacred mushrooms of Mexico, identified them, isolated the active agent, and proceeded to the determination of its properties. What is there for us to do now? Our field of research broadens as we progress. Let me outline, what seems to me, in the anthropological field, the course to persue. Remember that all I shall say is speculative, awaiting confirmation.

We are dealing here with an authentic form of the religion of primitive men. Let me repeat what I said before: that it would be an error to bracket the hallucinogenic mushrooms with alcohol, as just another

drug that serves as an escape for man. The mushroom, despite its potency, is a dying agent. In the primitive world its survival is spotty, although there is evidence that its use was widespread long ago. It survives only in peripheral cultures, among the most isolated and neglected peoples, in Siberia, in Borneo, in New Guinea, until recently in Peru, and in Mexico. At an early stage in the evolution of a culture, it serves as the great mediator with God for peoples who are just beginning to be familiar with the idea of God.

The animal kingdom does not know God; it has no conception of the religious idea. The animal cannot imagine horizons beyond the horizon it has actually seen, a past earlier than it has experienced, a future beyond the immediate future, planes of existence other than this one in which we find ourselves. There must have come a time when man, emerging from his bestial past, first grasped these possibilities, vaguely, hesitantly; when he first knew the awe that goes with the idea of God. Perhaps these ideas came to him unaided, by the light of his dawning intelligence. I suggest to you that, as our most primitive ancestors foraged for their food, they must have come upon our psychotropic mushrooms, or perhaps other plants possessing the same property, and eaten them, and known the miracle of awe in the presence of God. This discovery must have been made on many occasions, far apart in time and space. It must have been a mighty springboard for primitive man's imagination. The secret of the miraculous discovery would be closely guarded, and it would leave little trace, other than by ricochet in folklore, in legend, and in the etymology of relevant words. From the beginning of history there have been seers, mystics, prophets, and poets who have seemed to possess the secret vision of eternal values. They achieved this by fasting and other ascetic practices or, perhaps, as in the case of Blake and Keats, by their abnormal sensitivity. Blake's description of the poetic gift is singularly apt for the experience of the mushroom agape: "He who does not imagine in a stronger and better light than his perishing mortal eye can see, does not imagine at all." The divine mushroom would open up the world of visions to far greater numbers, and the kingdom of God would be within reach of everyone who possessed the sacred secret. The Kingdom of God would be within you.

The ceremony we attended in southern Mexico was a true agape, a love-feast, a Holy Supper, in which we all felt the presence of God, in which the Element carried its own conviction in the miracles it performed within us. The faithful were not obliged to accept the dogma of Transubstantiation in order to know that they had partaken of the body of Christ. (How startling it is that the ancient Aztecs called this Element by the same name that we use for the Bread and Wine of the Eucharist—God's Flesh!) May not the sacred mushroom, or some other natural hallucinogen, have been the original element in all the Holy Suppers of the world,

being gradually replaced by harmless Elements in a watering down of the original fearful sacrament? May this not be the explanation of the Archetypes, the Ideas, of Plato? The ancient Greeks never revealed the secret of the Eleusinian mysteries, yet many must have known it and whispered to each other about it. We know only that the initiates drank a potion and later in the night knew a great vision. The Greeks, who were the fathers of pure reason, reserved a portion of their minds for the mystical element, the mysteries of Eleusis, the oracle at Delphi, the daemon of Socrates. No one knows for sure what beverage the ancient Hindus meant by the *soma*, nor what was the origin of the *ling chih* of the Chinese, the divine mushroom of immortality. Here is a missing element in our knowledge of these cultures, one that possibly can now be identified by the methods that we have used in our quest of the sacred mushroom.

There remains one question that some may be asking themselves, and that I gladly answer. How is it that I, a banker, and my wife, a pediatrician, have gone into these remote territories, and how does it come about that I write about these subjects? Our mushrooms impinge on a multitude of disciplines: in science, on mycology, chemistry, psychology, and medicine, in the humanities, on folklore and mythology, philology, anthropology, archeology, history, and religion. How does it come about that laymen without academic qualifications in any of these disciplines are so bold as to address a scientific body on these subjects?

My wife and I began to gather our material long ago, in 1927, on an August afternoon in the Catskills, as we strolled along a mountain path on the edge of a forest. She was of Russian birth and I am of Anglo-Saxon ancestry. I knew nothing of mushrooms and cared less. They were for me rather repellent and, like as not, deadly poisonous. In the years that we had known each other, I had never discussed mushrooms with my wife. Suddenly she darted away from my side: she had seen a forest floor carpeted with mushrooms of many kinds. She knelt before them, called them by endearing Russian names, and over my protests insisted on gathering them in her dress and taking them back to our lodge, where she went so far as to cook them and eat them—alone. My wife adored mushrooms, though she had never studied them or possessed a book about them. What she knew about them she had picked up at her mother's knee. The Great Russians experience a love for mushrooms that passes belief, that borders on the abnormal, just as we Anglo-Saxons are abnormally afraid of them.

This episode made so deep an impression on us that from then on, as circumstances permitted, we gathered all the information that we could about the attitude of various peoples toward mushrooms—what kinds they know, their names for them, the etymology of those names, the folklore and legends in which mushrooms figure, references to them in

proverbs and literature and mythology. We were interested in what untutored folk knew about mushrooms, those who had never seen a book on the subject, but knew only what had come down by oral tradition from their ancestors. Like stout Cortez, awed by the spectacle of the Pacific from his peak in Darien, we found we were privileged to tread a virgin field ripe for exploration. Slowly it dawned on us that the peoples of Europe were divided ethnomycologically into two groups, those who adored mushrooms and those who had an exaggerated fear of them and loathed them—the "mycophiles" and the "mycophobes," words that we coined. The objective evidence supporting this hypothesis was reenforced by myriad clues to be found in philology and folklore. A bold surmise gradually gripped us: perhaps our remote ancestors had worshipped the mushroom. This would explain our evidence, for that which is worshipped is both adored and feared, both holy and unclean. We traveled far and wide, to Lapland, to the Basque country, to Friesland, until we had assembled what seemed to us an impressive body of clues. Like the long slow swell that rocks the ocean days after the mighty hurricane has passed, so our cold, fossilized evidence, for all its scholarly inertness, seemed to us to betoken, when assembled for the first time and properly read, the terror and adoration that had once gripped our primitive ancestors long ago, perhaps before history began. We postulated the cult of a divine mushroom, as astronomers postulate the presence of an astral body without having seen it, deducing its presence from the behavior of other bodies. The question remained: if mushrooms were worshipped, which mushrooms and why?

We now cast our net further afield and, in our inquiries, embraced all of the Eurasian land mass. What was our surprise and delight to discover that there are peoples in Siberia who have worshipped a certain kind of mushroom from antiquity to our own time. They are the most primitive tribes in that primitive country, the Paleo-Siberian communities. We found that the use of mushrooms for ritualistic purposes was known in New Guinea, in Borneo. Then we went to Mexico, on our very doorstep. I have told you about our work there.

Perhaps we were helped, rather then hindered, by our lack of training in any of the disciplines that we needed. An academic scholar or scientist would have hesitated to tread where we wandered freely. In the course of our journeyings, both intellectual and geographical, we drew on the specialized knowledge of hundreds of informants, ranging from untutored country folk to academicians. In a sense my wife and I felt that we were merely the lens through which the light of their information was focused on the screen of our design. If the theories that we advance have any validity, the credit goes primarily to our informants. We wish we could cite all of them here. We wish we could cite at least all of the principal ones, men such as Robert Graves of Majorca, Spain; Adriaan Barnouw of New York, N.Y., Richard Schultes of Harvard University,

Cambridge, Mass., and Gordon Ekholm of the American Museum of Natural History, New York, N.Y. There are, however, two men we shall cite to whom we owe a debt that we can never repay, without whose help we would never have brought our book to term.

First, there is that prodigious scholar and teacher, Roman Jakobson, of Harvard University and the Massachusetts Institute of Technology Cambridge, Mass. From the day we met him during World War II, he has encouraged us, he has pursued us relentlessly, plied us with rich material, with ideas, with questions, never letting us slow up, driving us on to get out our book. Preeminent as a Slavicist, as a philologist, as a linguist, as a folklorist, as a cultural historian, as a pioneer in the new science of communications, himself fertile in all these fields, electrifying as a teacher, he is truly one of the great intellects of our time, and withal abounding in those human qualities that endear him to his students and disciples. It has been our pride that we gained his friendship and captured his interest in our researches.

Then there is Roger Heim. We met him for the first time in 1949 in Paris, when we intruded into his presence in his laboratory, wholly unknown to him, without academic qualifications, without introduction except for a telephone call from a colleague who himself did not know us. From the beginning he has been our ever-loyal, ever-patient guide in all matters mycological. I need not say how difficult a scientific discipline his is. His dedication to it is entire, his knowledge of it encyclopedic. Beyond the horizons of mycology, he commands in an astonishing way the realms of general science and the humanities. In fact, for him all science is only an extension of the humanities, a frontier that men are now exploring and that they are incorporating into the ever-accumulating body of human knowledge and human culture. Editor of the *Revue de Mycologie*, Director of the *Laboratoire de Cryptogamie*, author of *Les Champignons d'Europe*, a mushroom manual of new conception that surpasses anything we have in the English language, Director of the *Muséum National d'Histoire Naturelle, Membre de l'Institut*, occupying the very chair and the very room that Buffon occupied, an accomplished stylist in the French language, he exemplifies the finest traditions of French science and French culture. Without his ever-ready hand to help us over the hard places, without his authoritative voice to support us in our field work, we should never have dared to persevere. I am honored to have the privilege of paying this tribute to a great Frenchman, a great scientist, an eminent exponent of the best in the Western tradition of humane and scientific letters.

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DIVISION OF OCEANOGRAPHY AND METEOROLOGY

THE UNITED STATES NAVY HYDROGRAPHIC OFFICE SHIP-ROUTING PROGRAM*

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Introduction

In recent years, the improvement in longer range wind forecasts, the development of synoptic and prognostic wave charts, and the increased knowledge of applied meteorology and oceanography by shipmasters have led to a renewed interest in optimum, or least-time, ship routing. For the last 5 years, a number of large maritime companies have been using the ship-routing services of commercial weather consultants. In October 1957, after an extensive evaluation of the ship-route forecasts provided by the United States Navy Hydrographic Office (Hydro), the United States Navy Military Sea Transport Service (MSTS) secured optimum routing for all their ships. This included passenger and cargo ships, tankers, and aircraft carriers, of 3,000 to 25,000 gross tons and 10- to 20-knot speeds. More recently, the navy has assigned certain destroyers and cruisers as test vessels for optimum routing of military units.

The Problem

The speed of advance of a ship is a function of several variables, the most important of which are ocean currents, winds, and waves. Northern Hemisphere ocean currents, except in the case of the Gulf Stream and the Kuroshio Current, are relatively weak and unreliable. Mean ocean currents are indicated on Hydro's monthly climatic current charts, pilot charts, and sailing directions.

For its effect on ship speed, wind must be considered although, in the Hydro routing technique, this factor in most cases is automatically incorporated into the wave considerations.[1]

In its simplest form, wind resistance to a ship can be expressed[2] by

$$R = KAv^2$$

where A = area of ship above surface normal to the wind, v = longitudinal component of relative velocity between wind and ship, and K = 0.0048 coefficient (when using pounds; feet, knots).

*This paper, illustrated with slides, was presented at a meeting of the Division on January 27, 1959.

Of primary importance in wind effect on ship speed is deck structure.[3,4] In addition to the direct effect of wind resistance there is a tendency for the ship to yaw; both of these factors reduce the ship's forward speed. In a study by Hughes,[4] a 32-knot wind from 30° off the bow reduced the speed of a 16-knot Victory ship by 11 per cent and, from 10° off the stern, increased the speed 1 per cent. This varies with the ratio of ship area above water to the area of the ship under water. In another study[5] on 9 vessels and including 2700 observations, a following wind of 15 to 20 knots increased ship speed by 2 per cent, but when the wind increased to 20 to 25 knots, the wave action generated by it exactly countered the wind force. In general, all headwinds decrease the speed of a ship, light following winds increase ship speed by small amounts, and strong following winds, due to wave action, result in a decrease of ship speed.[6]

In order to relate the effects of sea conditions on the performance of a ship, it is necessary to know the propulsion characteristics of a given ship under all expected sea conditions. To attack the problem theoretically would require integration of many complex factors, including resistance of the waves, skin friction of the hull, eddy resistance, the vessel's profile wave characteristics and, last but not least, the reaction of the shipmaster, who is responsible for the safety of the ship and the comfort of the passengers. James[7] solved this problem empirically by extracting ship speed versus wave height from ships' logs. Victory ships were used in his original work. The angle of encounter between the vessel and the waves was classified as follows: head seas 45 degrees on either side of the bow, following seas 45 degrees on either side of the stern, and beam seas on the remaining quadrants. The ship speeds were plotted against wave heights for each classification and reduced by the least-squares method to a mean curve, as shown in FIGURE 1. After this preliminary work, James included more observations, revised his curves, and derived similar performance curves for other types of vessels (FIGURE 2).

Because of the complex interrelation between wind and waves, this method automatically includes most of the wind effect on ship speed. When strong winds arise quickly and the sea has not yet fully arisen,[8] as in a frontal passage or rapid cyclogenesis, wind effect is handled separately and subjectively. In addition, James' solution includes the voluntary decrease in speed by the master to ease his ship in heavy seas. It clearly shows that the state of the sea is the largest single factor affecting a ship's speed.

Optimum Track Computation

In order to compute an optimum track or, for this paper, a least-time track, three basic charts are required.[9,10] They are, in order of their use, meteorological charts, wave charts, and ship speed charts. A brief discussion of these charts follows.

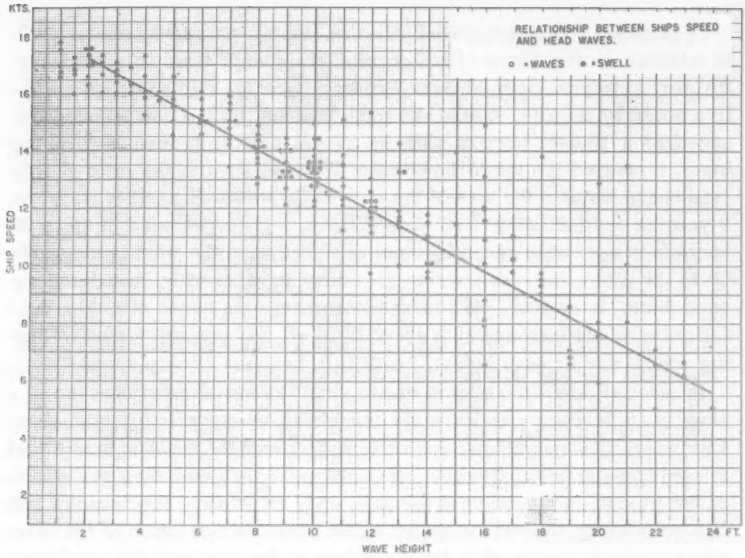

FIGURE 1.

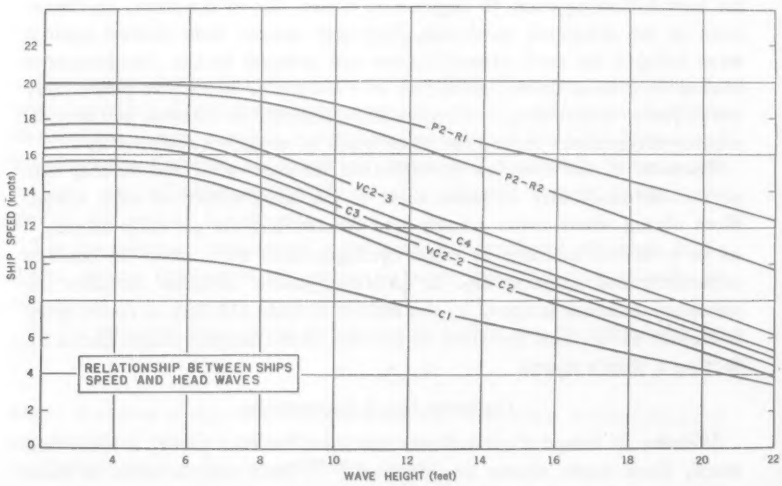

FIGURE 2.

Meteorological charts. The Weather Bureau charts used in Hydro's ship routing program are: (1) the latest Northern Hemisphere synoptic sea-level charts; (2) the 30-hour prognostic sea-level charts, both issued every 6 hours by the National Weather Analysis Center (NWAC); and (3) the 5-day forecast prepared 3 times a week by the Extended Forecast Section (EFS). The synoptic and the 30-hour prognostic weather charts are important in understanding the state of the sea in the present and the immediate future. However, because the 5-day forecast is of sufficient duration to be operationally practical for most vessel types, it is used to the greatest extent. The part of the 5-day forecast used in route computations is the sequence of 5 prognostic sea-level maps centered at 24-hour intervals.

Wave charts. There are two types of wave charts: the synoptic, which shows the latest observed wave conditions; and the prognostic, which shows the expected wave conditions for a specified future time. Synoptic wave charts are analyzed directly on the synoptic sea-level maps from NWAC. All wind and wave conditions reported by ships at sea are considered and drawn for. The resulting chart (FIGURE 3) shows isopleths of wave heights for 3-foot intervals and the direction that the major wave trains are moving.

In areas where there are insufficient data, theoretical wave heights are derived.[8] This can be done if the wave heights on the previous day and the surface wind velocity, fetch, and duration of that wind are known.

The synoptic wave chart enables the ship route forecaster to visualize sea conditions quickly over large areas. Observations of weather and waves are taken every 6 hours by most ships; hence 4 synoptic wave charts could be prepared daily.

Prognostic wave charts (FIGURE 4) are prepared on the 5-day prognostic weather maps obtained from EFS. At numerous points on each map, wind speed and direction are converted to wave heights, using indicated fetch and estimated duration.[8] The swell, or decaying wave from the previous wave map, is incorporated by adding its energy value to that of the wind waves. The result is the significant wave height and direction at each point. Again, as in the synoptic wave chart, isopleths of wave height for 3-foot intervals are drawn and the directions of movement of the major wave trains are indicated. Discretion should be used in the selection of grid points. Where the wind pattern is rapidly changing, as in a frontal zone, many points are needed. Conversely, where there is little change in wind over a large area, as near the center of a large anticyclone, very few points are required.

In practice, the ship route forecaster draws his synoptic wave analysis; he then draws a prognostic wave chart on each of the 5 weather prognoses in the 5-day forecast. This gives him the latest observed conditions and and a continuum of conditions for 5 days.

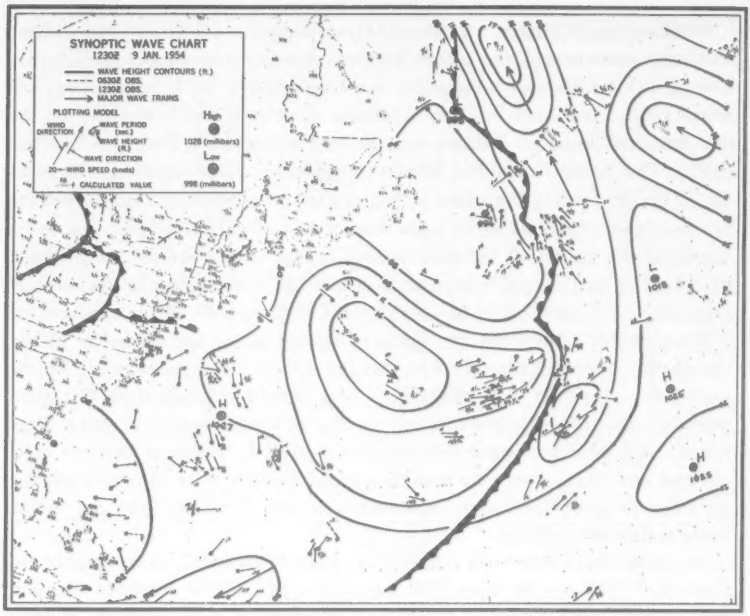

FIGURE 3. Synoptic wave chart.

Ship speed charts. Each isopleth of wave height on the prognostic wave chart is transformed into an isopleth of ship speed by reference to the ship performance curves. Since a ship's speed at a given point is a function of waves and current and (assuming constant power) the bearing of the ship to the direction of these variables, the preparation of a ship speed chart is complicated. It may be necessary to use more than one ship performance curve, and corrections for currents may be required. In practice, only those currents with 33 per cent reliability of direction and a speed of more than 0.5 knots are included in this correction, since lesser values can safely be neglected.[9] A ship speed chart is drawn over each of the prognostic wave charts for an area that includes at least the 24-hour advance of the ship, centered in time, on each chart.

Construction of Least-Time Track

Laying out the least-time track is a relatively simple operation after the basic charts have been completed. A great circle track is laid out between origin and destination on a blank base, the same scale as the ship speed chart (FIGURE 5). From the point of origin, diverging random

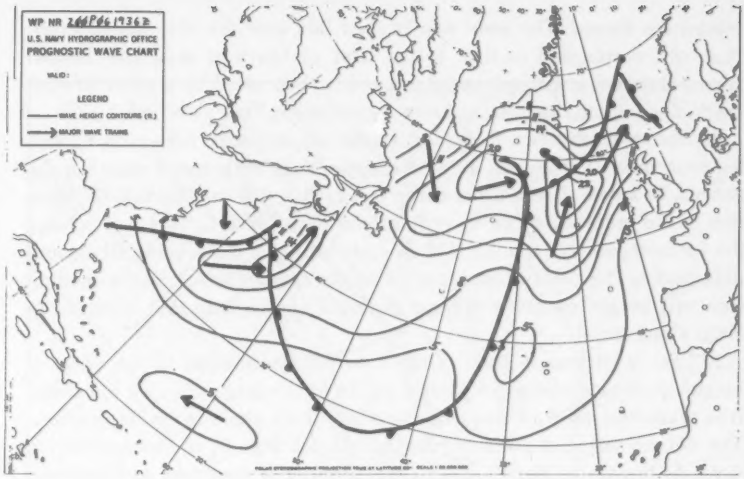

FIGURE 4. Prognostic wave chart.

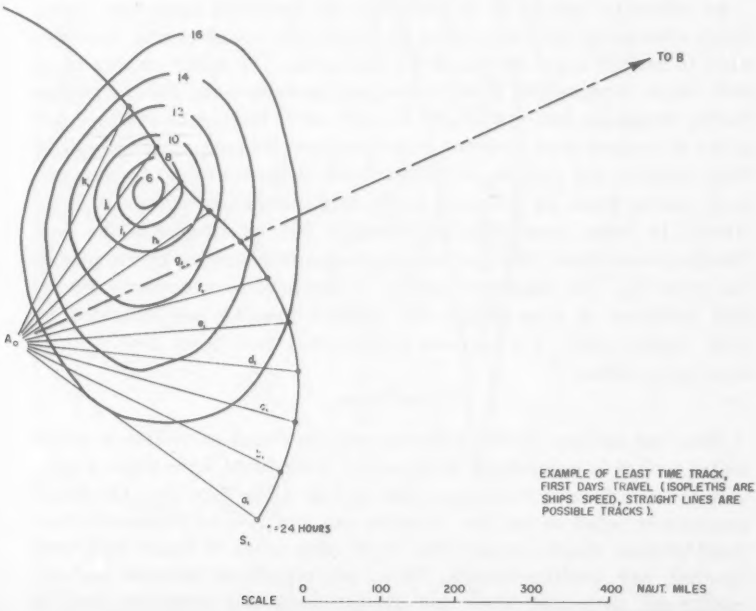

FIGURE 5. Least time track, first day.

tracks are drawn. The base map is then laid over the ship speed chart that will correspond in time to the first 24 hours at sea. The 24-hour travel distance at the appropriate speed is then noted by a point on each track. By joining the points, curve S_1 (FIGURE 5) is obtained.

As shown in FIGURE 6, random tracks are extended normal to S_1 and the procedure is repeated, using the appropriate ship speed chart for the second 24 hours at sea. Thus curve S_2 (FIGURE 6) is obtained. By iteration of the process, curve S_5 is finally drawn. Curve S_5 is a line joining the farthest points to which a ship can advance in 5 days, using all reasonable tracks. The point of tangency of an arc dropped to S_5 from the destination will be the vessel's closest possible approach to that terminus in 5 days' steaming.

A line describing a great circle from the destination to the point of tangency, thence along the random tracks to the origin, is now the tentative least-time track. This is not the exact track given to the shipmaster. The determination of the most desirable track from S_5 to the destination depends largely on the 30-day outlook from EFS, predicted and observed storm tracks, and the climate of the area. In addition, such hazards as sea ice and bergs, shoal areas, and jutting land masses may require revision of the track.

An alternate method of constructing the tentative least-time track, which eliminates the construction of formal ship speed charts, has been used to prepare many routes in the past year. The basic overlay chart with origin, destination, great circle path between them, and the random tracks emanating from the origin is still used. Instead of overlaying it on the ship speed chart, however, it is placed over the prognostic wave chart. Wave heights and relative direction (head, beam, following) are noted on each random track. By reference to the ship performance curves, S_1 (FIGURE 6) is drawn, connecting the points of 24-hour advance on the map. Similar computations with the remaining prognostic weather charts produce the curve S_5. The completed overlay is identical to FIGURE 6, except that notations of wave height and relative direction are indicated for each random track. For optimum tracks other than least time, this is especially useful.[10]

Surveillance

After the optimum track is determined, continual surveillance of the routed vessel is maintained. The track is recomputed three times a week with the new 5-day forecasts emanating from EFS. Each day, the ship's progress is noted on the four synoptic and four 30-hour prognostic sea-level weather charts. In turn, the routed ship sends to Hydro daily sea, weather, and position reports. Thus, any significant weather and sea conditions, unforseen when the original track was computed, can be avoided or taken advantage of to maintain optimum route conditions.

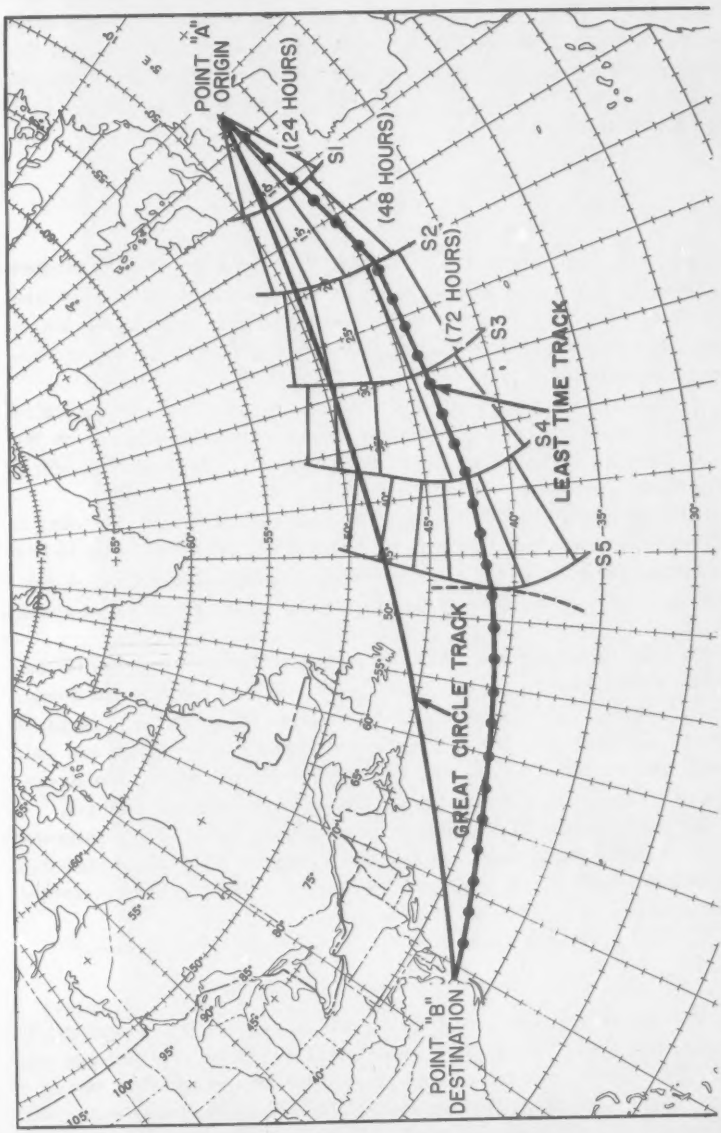

FIGURE 6. Calculation of least-time track: La Pallice, France to Norfolk, Va.

Frequently there are large storm areas through which the ship must pass, but the routed ship avoids bad weather more often than the non-routed ship.[8] Upon completion of an optimum route crossing, every ship-master sends in a performance report that summarizes the crossing. Departure and arrival times, both estimated and actual, fuel consumption, sea and weather conditions, and general remarks are included to help in the evaluation program.

Evaluation

Complete discussion of the evaluation of Hydro's ship-routing program is beyond the scope of this paper. It is a complex and often subjective process. This is true partly due to the intangibles, such as passenger comfort, but mostly due to lack of established normals to which to compare the performance of a routed ship. There are four approaches:

(1) *Statistical approach.* By this method, the performance of a routed vessel is compared to a normal performance of similar vessels on the same crossing. To date there are normals computed only for Victory ships on Atlantic crossings.

(2) *Control ship approach.* Two ships of identical type and similar schedules are required. One ship is routed, while the second ship is free to follow the standard track, or any track chosen by the master. A comparison of the performance of the two ships provides an excellent evaluation.

(3) *Theoretical approach.* The travel time of the routed vessel is compared to the theoretical time this vessel would have required along a standard track. To compute the theoretical travel time, the ship speed charts obtained from the appropriate synoptic weather maps and ship performance curves are used. By knowing the theoretical ship speeds over the entire crossing, the theoretical time en route is easily obtained.

(4) *ETA versus ATA.* This involves a comparison of the estimated time of arrival (ETA) to the actual time of arrival (ATA) of a routed ship. Frequently the master sets a new ETA after the optimum route is presented, thus complicating this evaluation approach.

TABLE 1 presents a summary of Hydro ship-routing evaluation.[11]

Conclusion

That benefits are derived from least-time ship routing is realized by many shipowners and masters and by MSTS. Assuming an average cost of 130 dollars an hour per ship at sea and an average time saving of 14.5 hours, there is an average saving of 2,000 dollars per crossing. With wider use of least-time ship routing, the maritime industry could realize savings of millions of dollars per month.

TABLE 1

SUMMARY OF EVALUATION

1. *Control vessel*		
Atlantic	Norfolk to Lisbon:	
	Crain VC2-AP2	191 hours
	McGraw VC2-AP2	208 hours
		17 hours
Pacific	Yokohama to San Francisco:	
	Kimbro VC2-AP2	298.5 hours
	Lawrence VIC VC2-AP3	303.5 hours (325.5)
		26 hours
	Average,	*21.5 hours*
2. *Theoretical control*		
Atlantic	10.7 hours	22 Crossings
Pacific	15.6 hours	10 Crossings
	Average, 13.2 hours	
3. *ETA versus ATA*		
Atlantic (actual ETA)	Control vessels	6.1 hours (lost)
	Routed vessels	2.5 hours
Pacific (actual ETA)	Control vessels	0.9 hours — 7 Crossings
	Routed vessels	11.9 hours — 9 Crossings
Pacific (standard ETA)	Routed vessels	30.1 hours — 9 Crossings
	Average, 11.5 hours	
4. *Statistical*		
Atlantic VC2-AP2 (15.5 Kt.)		8 hours
VC2-AP3 (17.0 Kt.)		12 hours
	Average,	*10 hours*

ESTIMATED OVER-ALL SAVING, 14.5 HOURS

However, optimum tracks are not necessarily least-time tracks. An aircraft carrier with a deckload of aircraft or any cargo vessel with a delicate deckload may require a smooth crossing with less regard for time en route.

In a military sense, ship routing can become a weapon in wartime. Just as vulnerable ships seek clouds and fog to escape the eyes of hostile

forces, vessels can be routed through seas and weather that will be to their advantage in any foreseen skirmish. An entire fleet, using least-time tracks, can increase its mobility by crossing an ocean one half to two days faster than by following a standard track.

Thus far, the development of optimum ship-routing techniques represents a substantial start in the direct application of sea-state conditions to marine navigation.

Improvements should be realized with the continual revisions of ship performance graphs. Several thousand observations are included in the present curves but, as additional performance data are received, the curves are continually revised. With sufficient observations, graphs could be derived for many of the complex conditions that make up the entire wave spectrum of the sea.

Some practical method will be devised for treating meteorological circulations as the dynamic systems that they are. Instead of assuming each day's prognostic weather chart as a steady state in which a ship travels for 24 hours, the changing wind fields should be integrated, in time, with the moving ship. This could be accomplished with proper use of the high-speed electronic computer.

A great step forward was taken by Namias [12] in 1958 in incorporating numerical methods in the 5-day forecast. Quantitative computations by the IBM 704 have replaced the older method of subjectively weighing the infinitely complex forces in the atmosphere. This has raised the level of skill in the 5-day forecast which, in turn, must increase the dependability of optimum ship routing.

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CONFERENCES HELD

DIVISION OF MYCOLOGY

GENETICS OF STREPTOMYCES AND OTHER ANTIBIOTIC-PRODUCING MICROORGANISMS

Conference Chairman: Waclaw Szybalski
Rutgers University, New Brunswick, N. J.

TUESDAY, JANUARY 6, 1959

Session Chairman: D. M. Bonner
Yale University, New Haven, Conn.

9:00 A.M. –

Greetings from the Academy – Karl Maramorosch, Chairman, Division of Mycology, The New York Academy of Sciences, New York, N. Y.; The Rockefeller Institute, New York, N.Y.

Introductory Remarks – D. M. Bonner, Yale University, New Haven, Conn.

"Genetic Interactions Within Heterokaryons of Streptomycetes" – S. G. Bradley, D. L. Anderson, and L. A. Jones, University of Minnesota, Minneapolis, Minn.

"Heterokaryotic Compatibility and Recombinations in *Streptomyces*" – D. H. Braendle, Abbott Laboratories, North Chicago, Ill. and Waclaw Szybalski, Rutgers University, New Brunswick, N. J.

"Genetics of *Streptomyces coelicolor*" – G. Sermonti and I. Spada-Sermonti, Instituto Superiore di Sanità, Rome, Italy.

"Cytogenetic Studies on *Streptomyces griseoflavus*" – H. Saito and Y. Ikeda, University of Tokyo, Tokyo, Japan.

Discussants: K. F. Gregory, Ontario Agricultural College, Guelph, Canada.
N. M. McClung, University of Georgia, Athens, Ga.
D. A. Hopwood, Cambridge University, Cambridge, England.
S. G. Bradley, University of Minnesota, Minneapolis, Minn.
D. H. Braendle, Abbott Laboratories, North Chicago, Ill.
Waclaw Szybalski, Rutgers University, New Brunswick, N. J.

Session Chairman: E. L. Tatum
The Rockefeller Institute, New York, N.Y.

2:00 P.M. –

Introductory Remarks – E. L. Tatum, The Rockefeller Institute, New York, N.Y.

"Genetics of Tetracycline-producing Streptomyces" – S. I. Alikhanian, All-Union Research Institute of Antibiotics, Moscow, U.S.S.R.

"Genetics of Penicillin Production" – G. Sermonti, Instituto Superiore di Sanità, Rome, Italy.

Discussants: E. L. Dulaney, Merck Sharp & Dohme, Rahway, N. J.
J. B. Clark, University of Oklahoma, Norman, Okla.
T. C. Nelson, Eli Lilly & Co., Indianapolis, Ind.
K. B. Raper, University of Wisconsin, Madison, Wis.

"Lysogenicity in *Streptomyces*" – M. Welsch, Université de Liège, Liège, Belgium.

Discussants: E. B. Shirling, Ohio Wesleyan University, Delaware, Ohio.
S. G. Bradley, University of Minnesota, Minneapolis, Minn.
W. Gold, Bzura, Inc., Keyport, N. J.
E. McCoy, University of Wisconsin, Madison, Wis.

SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

BIOLOGY OF THE PLEUROPNEUMONIALIKE ORGANISMS

Wednesday, January 14,
Thursday, January 15, and
Friday, January 16, 1959

Conference Chairman: D. G. ff. Edward
Virus Department, The Wellcome Research Laboratories
Langley Court, Beckenham, Kent, England

WEDNESDAY, JANUARY 14, 1959

MORPHOLOGY AND CLASSIFICATION

Session Chairman: Edwin M. Lerner, II
National Institutes of Health, Public Health Service, Bethesda, Md.

9:00 A.M. –

Greetings from the Academy – Robert L. Kroc, Chairman, Section of Biological and Medical Sciences, The New York Academy of Sciences, New York, N. Y.; Warner-Lambert Research Institute, Morris Plains, N. J.

"The Objective of the Conference" – D. G. ff. Edward, Virus Department, The Wellcome Research Laboratories, Langley Court, Beckenham, Kent, England.

"Morphology and Classification of PPLO" – E. A. Freundt, Statens Seruminstitut, Copenhagen, Denmark.

"Morphology of PPLO and L Forms of Bacteria" – Kurt Liebermeister, University of Frankfurt, Frankfurt, Germany.

"The Cell Wall of Bacterial L Forms and PPLO" – John T. Sharp, Department of Medicine and Bacteriology, Massachusetts General Hospital, Boston, Mass.

"Controversial Aspects of the Morphology of PPLO" – Louis L. Dienes, Massachusetts General Hospital, Boston, Mass.

"The Prevalence of PPLO" – Harry E. Morton, Department of Microbiology, The School of Medicine, University of Pennsylvania, Philadelphia, Pa.

This conference and the resulting monograph were supported in part by Research Grant. E-2572 from the National Institute of Health, Public Health Service.

"The Production of L Forms of Enterococci" – Willy Hymans and M. J.W. Kastelein, Research Laboratories, Department of Rheumatology, University Hospital, Leiden. The Netherlands.

"L Forms of *Proteus mirabilis*" – M. Medill-Brown, Wesley G. Hutchinson, and E. Cocklin, University of Pennsylvania, Philadelphia, Pa.

Discussion Leader: Louis L. Dienes, Massachusetts General Hospital, Boston, Mass.

ISOLATION AND PROPAGATION

Session Chairman: John B. Nelson
The Rockefeller Institute, New York, N. Y.

2:00 P.M. –

"Isolation and Identification of PPLO" – Sarabelle Madoff, Massachusetts General Hospital, Boston, Mass.

"Problems in the Isolation and Identification of Avian PPLO" – Julius Fabricant, New York State Veterinary College, Cornell University, Ithaca, N. Y.

"The Recovery, Propagation, and Characteristics of T Strain PPLO Isolated from Human Cases of Nongonococcal Urethritis" – Maurice C. Shepard, Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

"The Differentiation of Avian PPLO to Bacterial L Forms" – Robert F. Gentry, Department of Veterinary Science, Pennsylvania State University, University Station Pa.

"Derivation of Gram-Positive Cocci From PPLO" – William H. Kelton, U.S. Department of Agriculture, Department of Veterinary Science, The Pennsylvania State University, University Park, Pa.

"Growth Curve Studies of PPLO" (read by title) – William H. Kelton, U. S. Department of Agriculture, Department of Veterinary Science, The Pennsylvania State University, University Park, Pa.

"PPLO Contamination in Tissue Cultures" – George Rothblat, Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

"Intracellular Growth of PPLO in Tissue Culture and *in Ovo*" – Leonard Hayflick and Warren Stinebring, The Wistar Institute of Anatomy and Biology, Philadelphia, Pa. and Rutgers University, Institute of Microbiology, New Brunswick, N. J.

"The Behavior of Murine PPLO in HeLa Cell Cultures" – John B. Nelson, The Rockefeller Institute, New York, N. Y.

Discussion Leader: John B. Nelson, The Rockefeller Institute, New York, N. Y.

Session Chairman: Louis L. Dienes
Massachusetts General Hospital, Boston, Mass.

8:00 P.M. –

"Relation of PPLO to Bacteria" – Paul F. Smith and George Rothblat, Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

"Reversion of Avian PPLO to Bacteria" – K. A. McKay and R. B. Truscott, Ontario Veterinary College, Guelph, Ontario, Canada.

Round Table Discussion – "The Classification of PPLO and Their Possible Relationship to Bacteria."

Discussants: D. G. ff. Edward, The Wellcome Research Laboratories, Langley Court, Beckenham, Kent, England.
Emmy Klieneberger-Nobel, The Lister Institute of Preventive Medicine, London, England.
E. A. Freundt, Statens Seruminstitut, Copenhagen, Denmark.
Kurt Liebermeister, University of Frankfurt, Frankfurt, Germany.
J. Roux, Faculty of Medicine, Université de Montpellier, Montpellier (Hérault), France.
Miguel Rubio-Huertos, Instituto Jaime Ferran de Microbiologia, Madrid, Spain.
J. Brisou, École d' Application du Service de Santé de l'Hôpital Maritime St. Anne, Toulon, France.

THURSDAY, JANUARY 15, 1959

PHYSIOLOGY

Session Chairman: Paul F. Smith
Department of Microbiology, School of Medicine,
University of Pennsylvania, Philadelphia, Pa.

9:00 A.M. –

"Chemical Composition of PPLO" – R. J. Lynn, University of Pittsburgh, Pittsburgh, Pa.

"Nutrition and Metabolism of *Mycoplasma mycoides* – var. *mycoides*" – A.A.W. Rodwell, Animal Health Research Laboratory, Victoria, Australia.

"Nutritional Requirements of PPLO and Their Relation to Metabolic Function" – Paul F. Smith, School of Medicine, Department of Microbiology, University of Pennsylvania, Philadelphia, Pa.

"Serological and Physiological Comparisons of PPLO from Various Sources" – Mark E. Tourtellotte and Richard E. Jacobs, Department of Animal Diseases, University of Connecticut, Storrs, Conn.

"Products of Carbohydrate Metabolism by PPLO" – Harold Niemark and M.J. Pickett, Department of Bacteriology, University of California, Los Angeles, Calif.

"Oxidative Metabolism of PPLO" – R. J. Lynn, University of Pittsburgh, Pittsburgh, Pa.

"Amino Acid Metabolism of PPLO" – Paul F. Smith, Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

SEROLOGY AND CHEMOTHERAPY

Session Chairman: Harry E. Morton
Department of Microbiology, School of Medicine,
University of Pennsylvania, Philadelphia, Pa.

2:00 P.M. –
"Pathological, Serologic, and Cultural Characteristics of Ten Avian Strains of Pleuropneumonialike Organisms" –R.W. Moore, L.C. Grumbles, and J.N. Beasley, Texas Agricultural Experiment Station, College Station, Texas.

"The Use of the Hemagglutination-Inhibition Test for the Control of Chronic Respiratory Disease of Chickens" – J.F. Crawley, Connaught Medical Research Laboratories, University of Toronto, Dufferine Divi-Division, Toronto, Canada.

"Thermostability of Serum and Plasma to be used in PPLO Agglutination Test" – M.S. Cover, W. J. Benton, and M.A. Whelna, University of Delaware Agricultural Experiment Station, Newark, Del.

"Comparison of PPLO Strains from Tissue Cultures by Complement Fixation" – Lewis M. Coriell, David P. Fabrizio, and S. Robert Wilson, South Jersey Medical Research Foundation, Camden, N.J.

"The *in Vivo* Development of Antibiotic-Resistant Strains of *Mycoplasma gallinarum*" – O.H. Osborn, B.S. Pomeroy, and C.F. Mataney, College of Veterinary Medicine, University of Minnesota, St. Paul, Minn.

"The Effect of PPLO on the Chicken Chorioallantoic Membrane and resistance to Antibiotics" – Theodor Masemann and H. Röckl, Dermatologische Klinik and Poliklinik der Universität München, Munich, Germany.

"Antibiotic Control of an Experimental Infection of Chickens with *Mycoplasma gallinarum*" – J.S, Kiser, F. Popken, and J. Clemente, Research Division, American Cyanamid Company, Pearl River, N.Y.

Discussion Leader: Harry E. Morton, Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

FRIDAY, JANUARY 16, 1959

HUMAN PATHOLOGY

Session Chairman: Maurice C. Shepard
Department of Microbiology, Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

9:00 A.M. –

"Pathogenicity and Immunology of Organisms of the Pleuropneumonia Group" – Emmy Klieneberger-Nobel, Lister Institute of Preventive Medicine, London, England.

"Morphology and Pathogenicity of L Forms of *Clostridium tetani* Induced by Glycine" – Miguel Rubio-Huertos and C. Conzalez Vazquez, Instituto Jaime Ferran de Microbiologia, Madrid, Spain.

"The Occurrence of Organisms of the Pleuropneumonia Group in External Genitalia in Female Children" – Jorge Olarte, Hospital Infantil, Mexico, D.F., Mexico.

"Incidence of PPLO in Rectal Cultures" – Robert L. Berg and Louis Dienes, Massachusetts General Hospital, Boston, Mass.

"The Incidence and Clinical Significance of PPLO in the Human Female Genital Tract" – Alan Rubin and Harry E. Morton, Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

"Uveitis and Pleuropneumonialike Organisms" – Malvern C. Holland, U.S. Public Health Service Hospital, Chicago, Ill.

"Cultivation of PPLO from Reiter's Syndrome, Including One Instance of Laboratory Cross-Infection" – William C. Kuzell, and Eldon A. Mankle, Sanford University School of Medicine, San Francisco, Calif.

"Pleuropneumonialike Organisms and L Forms of Bacteria" (read by title) – R. Minck and A. Kirn, Institut d'Hygiène et de Bacteriologic, Faculté de Médicine, Universite de Strasbourg, Strasbourg, France.

"Experimental Polyarthritis of Rats due to Pleuropneumonialike Organisms *(Mycoplasma arthritidis)*" – William C. Kuzell, Eldon A. Mankle, and Aileen Yamate, Stanford University School of Medicine, San Francisco, Calif.

Discussion Leader: Maurice C. Shepard, Department of Microbiology, Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

ANIMAL PATHOLOGY

Session Chairman: Erwin L. Jungherr
Department of Animal Diseases, University of Connecticut,
Storrs, Conn.

2:00 P.M.

"Observations on the Type Species *Mycoplasma mycoides*" – Stanley Piercy, The Wellcome Research Laboratories, Langley Court, Beckenham, Kent, England.

"Porcine Polyserositis with Arthritis – Insolation of a Fastidious Pleuropneumonialike Organism and *Hemophilus Influenzae-suis*" – James G. Lecce, North Carolina State College, Veterinary Section, State College Station, Raleigh, N.C.

"The Characteristics of PPLO Isolated from the Genital and Respiratory Tracts of Cattle" – Norman O. Olson, W.J.R. Seymour, A.D. Booth, and L. Dozsa, University of West Virginia, Morgantown, W. Va.

"Patterns of Reaction in Infection with a Virulent PPLO from Goats" – Donald R. Cordy and Henry E. Adler, School of Veterinary Medicine, University of California, Davis, Calif.

"Organisms of the Pleuropneumonia Group of Avian Origin: Their Classification into Species" – D.G. ff. Edward and A.D. Kanarek, The Wellcome Laboratories, Langley Court, Beckenham, Kent, England.

"Mycoplasma, the Cause of Chronic Respiratory Disease" – Henry E. Adler, School of Veterinary Medicine, University of California, Davis, Calif.

"The Experimental Reproduction of Chronic Respiratory Disease in Chickens" (read by title) – Edward M. Gianforte, Leonard M. Skamser, and Ross G. Brown, American Cyanamid Company, Princeton, N.J.

"Some Studies Upon Induced PPLO Insections in Young Chickens" – E. E. Ose, L.E. Barnes, F.O. Gossett, Agricultural Research Center, Eli Lilly and Company, Greenfield, Ind.

"Pathological and Immunological Observations Concerning Avian PPLO" – Olga M. Olesiuk and Henry Van Roekle, Department of Veterinary Science, University of Massachusetts, Amherst, Mass.

"The Pathology of PPLO and Other Agents in Chicken Embryos" – Harold L. Chute, Department of Animal Pathology, University of Maine, Orono, Me.

"Basic Pathological Responses to Avian PPLO in Chickens and Chicken Embryos" – Erwin L. Jungherr, Department of Animal Diseases, University of Connecticut, Storrs, Conn

Discussion Leader: Erwin L. Jungherr, Department of Animal Diseases, University of Connecticut, Storrs, Conn.

HAIR GROWTH AND HAIR REGENERATION

Saturday, January 31, 1959

Conference Chairman: Irwin I. Lubowe
New York Medical College, New York, N. Y.

SATURDAY, JANUARY 31, 1959

Session Chairman: William Montagna
Brown University, Providence, R. I.

9:00 A.M. –

Greetings from the Academy – Robert L. Kroc, Chairman, Section of Biological and Medical Sciences, The New York Academy of Sciences, New York, N. Y.; Warner-Lambert Research Institute, Morris Plains, N. J.

Opening Remarks – Irwin I. Lubowe, New York Medical College, New York, N. Y.;
William Montagna, Brown University, Providence, R. I.

"The Growth of the Hair Follicles in Waves" – Herman B. Chase and Gordon J. Eaton, Department of Biology, Brown University, Providence, R. I.

"Restitutive Growth in the Hair Follicle of the Rat" – Earl O. Butcher, Department of Anatomy, New York University, New York, N. Y.

"The Occurrence of Trytophan Metabolites in Hair and Feathers" – Gerbert Rebell and T. B. Fitzpatrick, Colgate-Palmolive Company, Jersey City, N. J.

"Electron Microscope Studies of Hair and Wool" – George E. Rogers, Commonwealth Scientific and Industrial Research Organization, Wool Textile Research Laboratories, Victoria, Australia.

"Innervation of the Hair Follicles" – Richard K. Winkelmann, Section of Dermatology, Mayo Clinic, Rochester, Minn.

"Newer Findings on the Enzymes and Proteins of Hair Follicles" – George E. Rogers, Commonwealth Scientific and Industrial Research Organization, Wool Textile Research Laboratories, Victoria, Australia.

2:00 P.M. –

PATTERN ALOPECIA

"Some General Aspects of the Problem of Baldness and Preliminary Studies of Baldness in an Experimental Animal" – Chairman, Department of Anatomy, State University of New York, Brooklyn, N.Y.

"Histological and Histochemical Changes in Baldness" – Richard A. Ellis, Department of Biology, Brown University, Providence, R. I.

Discussion

ALOPECIA AREATA

"The Clinical Aspects of Alopecia Areata, Totalis and Universalis" – Irwin I. Lubowe, Department of Dermatology, New York Medical College, New York, N.Y.

"Autografts in Alopecia" – Norman Orentreich, Skin and Cancer Unit, University Hospital, New York, N. Y.

"Evaluation of Pathological Changes in Alopecia Areata" – Eugene J. Van Scott, Dermatology Service, National Cancer Institute. Bethesda, Md.

NEOGENESIS OF HAIR FOLLICLES IN ADULT SKIN

"Neogenesis of Hairs in the Antlers of the Deer" – Robert E. Billingham, B. Mangold, and W.K. Silvers, Department of Anatomy, The Wistar Institute, Philadelphia, Pa.

"A Study on the Neoformation of Mammalian Hair Follicles" – William E. Straile, – Biology Department, Brown University, Providence, R.I.

"Neogenesis of Human Vellus Hair Follicles" – Albert M. Kligman, University Hospital, University of Pennsylvania, Philadelphia, Pa.

Summary – William Montagna, Brown University, Providence, R. I.

NEW MEMBERS

Elected January 22, 1959

SUSTAINING MEMBERSHIP

Boggs, Robert, M.D., Basic, Clinical Research. Director, Medical Research Program, National Fund for Medical Education, New York, N. Y.

Major, Stephen, M.D., Neuropsychiatry. Physician, Private Practice, Binghamton, N. Y.

Nelson, Fred L., M.D., Radiation Biology, Cancer Chemotherapy. Radiologist, Thompson-Brumm-Knepper Clinic, St. Joseph, Mo.

Trapold, Joseph H., Ph.D., Pharmacology. Director, Pharmacology Laboratories, Sandoz Pharmaceuticals, Hanover, N. J.

ACTIVE MEMBERSHIP

Adelson, Jerry J., D.D.S., Dentistry. Assistant Clinical Professor, Columbia University, New York, N. Y.

Allen, Gabriel, Engineering. Director of the Board, Allen & Company, New York, N. Y.

Allerhand, Jona, M.D., Bacteriology. Bacteriologist, Hillside Hospital, Glen Oaks, N. Y.

Altschuler, Bernard M., M.D., Obstetrics-Gynecology. Associate Professor, Seton Hall University, College of Medicine, South Orange, N. J.

Amies, Cleeve Russell, M.D., Bacteriology, Virology. Research Member, Connaught Medical Research Laboratories, University of Toronto, Toronto, Canada.

Anderman, Eugenie, M.D., Gynecology, Pediatrics. Physician, Private Practice, New York, N. Y.

Arnold, T. Ben., M.S., Petroleum Refining. Business Development, R. M. Parsons Company, Los Angeles, Calif.

Bally, Peter R., M.D., Lipid Metabolism. Assistant, Baker Research Laboratory, Harvard Medical School, Boston, Mass.

Balsam, Theodore, M.D., Enteric Disease. Master of Public Health Trainee, Johns Hopkins University, School of Hygiene & Public Health, Baltimore, Md.

Barry, Robert T., M.D., Surgery. Clinical Assistant, Surgical Staff, Hartford Hospital, Hartford, Conn.

Bauer, Charles Wilfred, Ph.D., Biochemistry. Director, Research, Massachusetts College of Pharmacy, Boston, Mass.

Becker, Robert J., M.D., Immunology, Hypersensitivity. Northwestern University, School of Medicine, Evanston, Illinois.

Bishop, James R., M.D., Corticosteroid-Tranquilizers. Physician, Private Practice, Salisbury, Md.

Blackwood, Unabelle R. Boggs, Ph.D., Chemical (Nutritional) Embryology Research Assistant, Poultry Department, University of Maryland, College Park, Md.

Brandaleone, Harold, M.D., Metabolism. Assistant Clinical Professor, New York University, College of Medicine, New York, N. Y.

Brandman, Harry, M.D., Psychiatry. Psychiatrist, Private Practice, Gary, Ind.

Brown, Hugh, B.S., Pharmacology. Junior Pharmacologist, Smith, Kline & French Laboratories, Philadelphia, Pa.

Brown, Irving, B.S., Biology. Biologist, Brooklyn, N. Y.

Brown, Robert W., M.D., Gynecology-Obstetrics. Assistant, Gynecology, Harvard Medical School, Boston, Mass.

Brunkhorst, Willa K., Ph.D., Lymphatic Tissue. Scientist, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

Cary, Stephen C., B.A., Zoology. Student, Yale University, School of Medicine, New Haven, Conn.

Charnicki, Walter F., Ph.D., Pharmaceutical Chemistry. Director, Pharmaceutical Research & Development, Smith-Dorsey Company, Lincoln, Nebr.

Chernow, Marvin Alexander, M.D., Pathology. Clinical Instructor, Yale University, New Haven, Conn.

Cloud, Luther A., M.D., Cancer. Assistant Medical Director, Equitable Life Assurance Society of the U. S. A., New York, N. Y.

Clyne, Irving M., M.D., Psychoanalytic Medicine. Psychoanalyst, Private Practice, New York, N. Y.

Conklin, Raymond LeRoy, M.D., Pharmaceutical Medicine. Medical & Research Director, Miles Laboratories, Inc., Elkhart, Ind.

Cosman, Bard, M.D., Plastic, Reconstructive Surgery. Assistant Resident, Surgery, Columbia-Presbyterian Medical Center, New York, N. Y.

Cushman, Robert G., M.D., Cancer Chemotherapy, Hematology. Instructor, University of Florida, School of Medicine, Jacksonville, Fla.

Dahlberg, Charles Clay, M.D., Psychoanalysis. Psychoanalyst, Private Practice, New York, N. Y.

Dardiri, Ahmad H., Ph.D., Biology. Assistant Professor, Animal Pathology, University of Rhode Island, Kingston, R. I.

Davis, Harry Louis, M.D., Clinical Pulmonary Physiology. Associate Director, Baptist Memorial Hospital, Memphis, Tenn.

Davis, John B., M.D., Surgery. Surgeon, Private Practice, Omaha, Nebr.

Decker, David G., M.D., Obstetrics-Gynecology. Assistant Professor, University of Minnesota, Minneapolis, Minn.

DeMaios, Joseph, B.S., Neurophysiology, Biophysics. Research Assistant, Columbia University, College of Physicians & Surgeons, New York, N. Y.

Derksen, Willard L., B.E.E., Physics. Supervisory Physicist, Naval Material Laboratory, New York Naval Shipyard, Brooklyn, N. Y.

Dickson, Carol C., M.D., Steroids. Associate, Pediatric Department, St. Luke's Hospital, New York, N. Y.

Douglas, J. Fielding, Ph.D., Biochemistry. Senior Biochemist, Wallace Laboratories, New Brunswick, N. J.

Efron, Daniel Herbert, M.D., Pharmacology, Biochemistry. Pharmacologist, National Drug Company, Philadelphia, Pa.

Embree, Larry J., M.D., Protein Metabolism, Neurology. Resident Physician, Peter Bent Brigham Hospital, Boston, Mass.

Feldman, Michael, Ph.D., Cancer, Immuno-Genetics. Senior Scientist, Weizmann Institute of Sciences, Rehovoth, Israel.

Forkner, Claude E., M.D., Internal Medicine. Professor, Cornell University Medical College, New York, N. Y.

Foster, John, M.D., Radiology. Director, Radiology, DePaul Hospital, Norfolk, Va.

Foy, Robert B., M.S., Biochemistry. Technical Director, Laboratories, Sparrow Hospital, Lansing, Mich.

Freundt, E. A., M.D., Microbiology. Statens Seruminstitut, Copenhagen, Denmark.

Friedman, Bernard, Ph.D., Applied Mathematics, Electromagnetic Theory. University of California, Berkeley, Calif.

Froeschels, Emil, M.D., Speech, Voice Therapy. Speech Consultant, Beth David Hospital, New York, N. Y.

Frost, Inglis F., M.D., Endocrine Function of Ovaries, Endocrine Clinic, Woman's Hospital, New York, N. Y.

Geyer, Georg, M.D., Endocrinology. Hematology. Staff Member, I. Medizinische Universitätsklinik, Vienna, Austria.

Gilbert, Richard D., Ph.D., High Polymers. Group Leader, Naugatuck Chemical Division, Naugatuck, Conn.

Golden, Benjamin I., M.D., Surgery. Chief Surgeon, Memorial General Hospital, Elkins, W. Va.

Golden, Clement H., M.D., Obstetrics-Gynecology. Chief, Gynecology, Irvington General Hospital, Irvington, N.J.

Good, Fredrick H., M.D., Surgery. Associate Professor, University of Colorado, School of Medicine, Denver, Colo.

Gordon, Samuel C., M.D., Psychology. Clinical Instructor, Psychiatry, George Washington University Medical School, Washington, D.C.

Gosliner, Bertram J., M.D., Psychoanalysis. Psychoanalyst, Private Practice, New York, N. Y.

Granwell, Leslie J., M.D., Biology. Physician, Private Practice, New York, N. Y.

Green, Albert, D.D.S., Pediatric Dentistry, Fluorides. Assistant, Columbia University, School of Dental & Oral Surgery, New York, N. Y.

Green, Frederick C., M.D., Pediatrics. Instructor, Harlem Hospital, School of Nursing, New York, N. Y.

Gross, Elmer Rupert, M.D., Dermatology, Syphilology. Attending Chief, The Delaware Hospital, Wilmington, Del.

Hammond, Denman, M.D., Hematology, Cancer. Assistant Professor, Pediatrics, University of Southern California, School of Medicine, Los Angeles, Calif.

Haskins, Arthur L., M.D., Obstetrics-Gynecology. Professor, University of Maryland, School of Medicine, Baltimore, Md.

Heller, Paul, M.D., Hematology, Clinical Enzymology. Research, Veterans Administration Hospital, Chicago, Ill.

Hoffman, Franklin G., M.D., Internal Medicine, Cardiology. Physician, Veterans Administration, Columbia, S. C.

Houck, John C., Ph.D., Enzymology. Director, Surgical Research Laboratory, Georgetown University Hospital, Washington, D. C.

Hughes, Elizabeth B., A.B., Microbiology. Instructor, Physics, University of Pennsylvania, School of Nursing, Philadelphia, Pa.

Jeub, Robert Phillip, M.D., Neurology, Psychiatry. Neurologist, Psychiatrist, Private Practice, Edina, Minn.

Kavan, Eva Mary, M.D., Anesthesiology. Assistant Professor, University of California, Los Angeles, Calif.

Keirns, Marvin Myrl, M.D., Radiology. Associate Radiologist, Baptist Memorial Hospital, Memphis, Tenn.

Kiplinger, Glenn F., Ph.D., Pharmacology. Instructor, Boston University, School of Medicine, Boston, Mass.

Knobloch, Henri, D.Sc., Biochemistry. Technical Director, Paris, France.

Kochwa, Shaul, Ph.D., Biochemistry. Assistant Director, Medical Research Institute, Beilinson Hospital, Petah Tikva, Israel.

Kraft, Nathan, B.A., Biology, Teaching Science. Teacher, General Science, Junior High School 44, New York, N. Y.

Krantz, Kennit Edward, M.D., Obstetrics-Gynecology. Assistant Professor, University of Arkansas, School of Medicine, Little Rock, Ark.

Landau, Joseph V., Ph.D., Cellular Physiology. Chief, Oncology Section, General Medical Research Laboratory, Veterans Administration Hospital, Albany, N. Y.

Levin, Robert H., Ph.D., Organic, Biochemistry. Assistant Director, Chemical Research, The Upjohn Company, Kalamazoo, Mich.

Lewis, Arthur James, M.D., Medicine. Instructor, New York University, College of Medicine, New York, N. Y.

Lewis, John L., M.D., Psychiatry. Instructor, Johns Hopkins University, Baltimore, Md.

Lieberman, E. R., B.S., Polymers, Proteins. Research Manager, Special Products Division, Ethicon, Inc., Somerville, N. J.

Litwer, Herman, M.D., Medicine, Radiology. Chief, Radiology Department, Veterans Administration Center, Washington, D. C.

Loch, Walter Edward Eric, M.D., Ear, Nose, Throat. Associate Professor, Johns Hopkins University, School of Medicine, Baltimore, Md.

Loewenstein, Werner R., Ph.D., Neurophysiology. Assistant Professor, Columbia University, College of Physicians & Surgeons, New York, N. Y.

Lusk, John Alexander, III, M.D., Hematology, Oncology. Associate Pathologist, The Moses H. Cone Memorial Hospital, Greensboro, N.C.

McCrum, W. R., Ph.D., Neurophysiology. Research Associate, Sherman Laboratories. Detroit, Mich.

McManus, Thomas J., M.D., Biochemistry, Biophysics. Assistant, Medicine, Harvard Medical School, Boston, Mass.

Martinez, J. Santos, Ph.D., Physiology. Assistant Professor, University of Puerto Rico, San Juan, Puerto Rico.

Micheel, Fritz K. H., Ph.D., Organic Chemistry. Director, Organic Chemistry Institute, University of Munster, Munster, Germany.

Miller, Robert Bayard, M.S., Neuropharmacology. Junior Pharmacologist, Smith, Kline & French Laboratories, Philadelphia, Pa.

Moazed, Mohamad, M.D., Surgery. Physician, Private Practice, Woodside, N. Y.

Modignani, Renato Litta, M.D., Endocrinology, Internal Medicine. Assistant Professor, University of Milan, Milan, Italy.

Monias, Michael B., M.D., Obstetrics-Gynecology. Obstetrician-Gynecologist, Private Practice, Annapolis, Md.

Morgenroth, Irvin, M.D., Anesthesia. Staff, Anesthesia Department, Albert Einstein Medical Center, Philadelphia, Pa.

Nabseth, Donald C., M.D., Vascular Surgery. Assistant Professor, Tufts University, School of Medicine, Boston, Mass.

Naghdi, Paul M., Ph.D., Elasticity, Plasticity. Professor, Engineering Science, University of California, Berkeley, Calif.

Nichols, Joseph Edward, M.D., Obstetrics-Gynecology. Assistant Attending, Orange Memorial Hospital, Orange, N. J.

Ohaneson, Edward Michael, M.D., Psychiatry, Psychoanalysis. Physician, Private Practice, Washington, D. C.

Orfei, Emilio, M.D., Human Pathology. Assistant Pathologist, Cook County Hospital, Chicago, Ill.

Oyama, Jiro, M.S., Insulin Action, Carbohydrate Metabolism. Biochemist, Food & Drug Administration, Washington, D. C.

Ozer, Faruk L., M.D., Hematology, Endocrinology. Instructor, University of Texas, Medical Branch, Galveston, Texas.

Patterson, Herman M., M.A., Biology, Geology. Science Teacher, Charles Evans Hughes High School, New York, N. Y.

Pellerin, Gilles, M.D., Cardiology, Physiology. Assistant, Cardiological Center, Boucicaut Hospital, Paris, France.

Phillips, Charles A. S., M.D., Surgery. Attending Surgeon, Moore Memorial Hospital, Pinehurst, N. C.

Piero, Sensi, Dr. Chem., Pharmaceutical Chemistry. Director, Physical Chemistry Department, Lepetit Inc., Milan, Italy.

Pietroluongo, Anthony L., M.D., Pathology. Associate Professor, Seton Hall University, School of Medicine, Jersey City, N. J.

Place, Virgil Alan, M.D., Medicine. Associate Director, Clinical Pharmacology, Lederle Laboratories, American Cyanamid Company, Pearl River, N. Y.

Poel, William E., Ph.D., Oncology. (Carcinogenesis). Research Associate, University of Pittsburgh, Graduate School of Public Health, Pittsburgh, Pa.

Quevauviller, André, Ph.D., Pharmacology, Hygiene. Professor, Paris School of Pharmacy, Paris, France.

Regan, Ellen F., M.D., Ocular Wound Healing. Associate, Ophthalmology, Columbia University, New York, N.Y.

Reinfrank, Ralph F., M.D., Internal Medicine, Neurology. Director, Outpatient Department, Hartford Hospital, Hartford, Conn.

Roberts, Lathrop Ellicott, M.D., Infectious Diseases. Assistant Resident, Third Medical Division, Bellevue Hospital, New York, N. Y.

Rosenthal, Mitchell S., A.B., Medicine. Medical Student, Flushing, N. Y.

Rosmerin, Philip F., Hair, Skin. Consultant, Cosmetic & Toilet Goods Industry. New York, N. Y.

Rowland, Alan L., M.D., Ear, Nose, Throat. Plastic Surgeon, Private Practice, La Mesa, Calif.

Salmon, Theodora N., Ph.D., Anatomy, Endocrinology. Assistant Professor, Hunter College, New York, N. Y.

Schoen, Edgar J., M.D., Pediatrics, Endocrinology. Staff Pediatrician, Kaiser Foundation Hospital, Oakland, Calif.

Schoenhard, Delbert E., Ph.D., *Salmonella pullorum*, Physiology. Associate Professor, Michigan State University, East Lansing, Mich.

Schretzmann, Rudolph C., M.D., Obstetrics-Gynecology. Director, Obstetrics-Gynecology Department, Hackensack Hospital, Hackensack, N. J.

Schultz, Elack, M.D., Gastroenterology, Neurology. Physician, Private Practice, Long Island City, N. Y.

Sellei, Camillo, M.D., Oncology. Professor, Országos Onkológiai Intézet, Budapest, Hungary.

Sessoms, Stuart M., M.D., Cancer Chemotherapy. Chief, Cancer Chemotherapy National Service Center, National Cancer Institute, Bethesda, Md.

Shaka, James Athan, M.D., Pathology. Research Trainee, Harvard Medical School, Boston, Mass.

Skiff, John V., Jr., M.D., Cancer Research. Physician, Private Practice, Internal Medicine, Castleton, N. Y.

Shipps, Hammell Pierce, M.D., Obstetrics-Gynecology. Assistant Clinical Professor, Medical College, Philadelphis, Pa.

Smith, Lloyd H., Jr., M.D., Endocrinology, Metabolic Disease. Chief, Endocrine Unit, Massachusetts General Hospital, Boston, Mass.

Smith, Malcolm McNeil, M.D., Medicine. Physician, Private Practice, Brooklyn, N. Y.

Smith, William S., M.D., Medicine. Physician, Private Practice, Chicago, Ill.

Sohlberg, Olof I., M.D., Surgery. Surgeon, Private Practice, St. Paul, Minn.

Sosa-Martinez, Jose, Ph.D., Virology. Chief, Virus Laboratory, National Industry of Chemical Pharmaceutics, Mexico D.F., Mexico.

Soulsby, Ernest J. L., Ph.D., Parasitology. Lecturer, University of Cambridge, Cambridge, England.

Spangler, Arthur S., M.D., Dermatology. Assistant, Harvard Medical School, Boston, Mass.

Spector, Elliot, Ph.D., Pharmacology. Instructor, Boston University, School of Medicine, Boston, Mass.

Spiegel, Allen J., Ph.D., Pharmaceutical Chemistry. Pharmaceutical Chemist. Chas. Pfizer & Company, Brooklyn, N. Y.

Stapinski, Stanley M., M.D., Metabolism Diseases. Physician in chief, Wilkes-Barre General Hospital, Wilkes-Barre, Pa.

Stauffer, Herbert M., M.D., Radiology. Head, Radiology Department, Temple University Hospital, Philadelphia, Pa.

Steelman, Richard L., B.A., Toxicology, Pathology. Toxicologist, Smith, Kline & French Laboratories, Philadelphia, Pa.

Sullivan, Julia C., M.P.H., Immunology. Research Assistant, Tissue Culture, Harvard Medical School, Boston, Mass.

Swatek, Frank E., Ph.D., Mycology, Virology, Bacteriology. Assistant Professor, Microbiology, Long Beach State College, Long Beach, Calif.

Sword, Christopher P., Ph.D., Rickettsial Diseases, Bacteriophages of Listeria. Post-Doctoral Research Associate, University of Kansas, Lawrence, Kans.

Taylor, Julius D., Ph.D., Chemical Pharmacology. Section Head, Abbott Laboratories, North Chicago, Ill.

Thomas, Donald M., M.D., Anesthesiology. Chief, Anesthesiology Section, 2500th U.S.A.F. Hospital, Mitchel Air Force Base, N. Y.

Thompson, George N., M.D., Neurology, Psychiatry. Neurologist, Psychiatrist, Lockheed Aircraft Corporation, Burbank, Calif.

Troen, Philip, M.D., Endocrinology. Instructor, Medicine, Harvard Medical School, Boston, Mass.

Tyree, Ella B., B.A., Radiobiology. Research Assistant, Sloan-Kettering Institute, New York, N. Y.

Urban, William, Medicine. Technical Assistant, Goldwater Memorial Hospital, Welfare Island, N. Y.

Valzelli, Luigi, M.D., Serotonin in Nervous Central System. Assistant, Pharmacology Institute, University of Milan, Milan, Italy.

Van Meier, Henry, M.D., Mental, Emotional Aspects of Aging. Medical Director, Pine Point Nursing Home, Stillwater, Minn.

Walter, George R., Jr., Ph.D., Microbiology. Bacteriologist, Givaudan Corporation, Delawanna, N. J.

Ward, Elisabeth B., M.D., Infertility. Associate Gynecologist, Presbyterian Hospital, Newark, N. J.

Warren, Marshall R., Ph.D., Pharmacology. Director, Pharmacology, Warner-Lambert Research Institute, Morris Plains, N. J.

Watson, Glenville Roy, B.S., Microbiology. Assistant Scientist, Warner-Lambert Research Institute, Morris Plains, N. J.

Weiner, Hannah B., M.A., Psychodrama. President, New York Institute of Psychodrama & Group Psychotherapy, Brooklyn, N. Y.

Weisman, Samuel A., M.D., Cardiology. Clinical Associate Professor, University of Southern California, Los Angeles, Calif.

Weiss, George B., A.B., Pharmacology. 2nd-Year Graduate Student, Vanderbilt University, Nashville, Tenn.

Weitzman, Mary C., M.A., Neuroendocrinology. Graduate Student, Albert Einstein College of Medicine, New York, N. Y.

White, Richard K., M.D., Orthopedic Surgery. Surgeon, Private Practice, Allentown, Pa.

Wilde, Guido, Ph.D., Psychology. Clinical Psychologist, Clinica Santo Tomas, Bogota, Colombia.

Williams, J. N., Jr., Ph.D., Intermediary Metabolism, Enzymology. Associate Professor, University of Wisconsin, Madison, Wis.

Wuest, Heinz M., Ph.D., Organic, Biochemistry. Associate Scientist, Sloan-Kettering Institute, New York, N. Y.

Zaman, Habibuz, M.S., Pathology, Virology. Assistant Professor, Pathology, Dow Medical College, Karachi, Pakistan.

Zellat, Joseph, Ph.D., Virology. Research Associate, Temple University, School of Medicine, Philadelphia, Pa.

Zick, Francis G., Yeasts. President, Yeast Products Corporation, Paterson, N. J.

STUDENT MEMBERSHIP

Basch, Ross S., B.A., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Beisaw, Norman E., A.B., Physiology. Student, New York University-Bellevue Medical School, New York, N. Y.

Cohn, Joseph D., B.S., Medicine. Student, New York University, New York, N. Y.

Davidson, Alan C., B.A., Medicine. Student, New York University, School of Medicine, New York, N. Y.

Fine, Albert S., M.A., Biochemistry. Graduate Student, New York University, New York, N. Y.

Frank, Arthur, M.S., Biochemistry. Student, New York University, College of Medicine, New York, N. Y.

Goldberg, Edwin, B.S., Neurophysiology. Student, The Columbia Institute of Chiropractic, New York, N. Y.

Gordon, Robert M., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Griffin, George Emmet, III, B.S., Medicine. Medical Student, New York University-Bellevue Medical Center, New York, N. Y.

Kaplan, Kenneth Charles, A.B., Medicine. Student, New York University-Bellevue Medical Center, New York, N. Y.

Legato, Marianne Jeanne, A.B., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Lipson, Steven, A.B., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Ludlum, David B., B.A., Polymers Protein Chemistry. Student, New York University, College of Medicine, New York, N. Y.

Malamy, Michael H., B.A., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Morley, Cassandra Britton, A.B., Medicine. Student, New York University, College of Medicine, New York, N. Y.

Nadolney, Carl H., B.S., Cell Physiology Research. Graduate Student, New York University, New York, N. Y.

Novick, Richard, B.A., Bacterial Metabolism. Student, New York University, New York, N. Y.

Scharff, Matthew, B.A., Allergy, Immunity. Student, New York University, College of Medicine, New York, N. Y.

Silverblatt, Fred, B.A., Medicine. Student, New York University-Bellevue Medical Center, New York, N. Y.

Ziring, Philip R., B.A., Medicine. Student, New York University, College of Medicine, New York, N. Y.